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George Chevelley

George Chevelley

Mashbury Hall

George Chevelley

TREATISE

ELECTRICITY

BY W. M.

THIS TREATISE IS NOT NECESSARILY TO BE READ
IN THE ORDER OF THE SECTIONS, BUT
THE STUDENT MAY BEGIN AT ANY PART

W. M. D. 1847

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A
TREATISE
ON
ELECTRICITY.

By B. W.

— Though every true step made in this philosophy brings us not immediately to the knowledge of the first cause, yet it brings us nearer to it, and on that account is to be highly valued.

Newton.

L O N D O N,
Printed, and sold by C. DAVIS in Holbourn,
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TREATISE

The Rev. J. W. W.

Granville Wheeler Esq.

ELECTRICITY.

J. W. W.

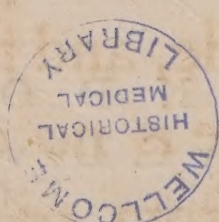
SIR,

UR knowledge of the causes and effects of

only proceed from experiments

known only by the

known that



T O

The R E V E R E N D

Granvill Wheeler Esq.

Of Otterden Place in Kent.

S I R,

O U R knowledge of natural causes and effects can only proceed from experiments judiciously made, and faithfully related. Nature is no otherwise known than from trials made

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upon

iv DEDICATION.

upon herself, and while we advance in these trials, step by step, as she leads the way, our researches generally prove just and accurate. It must indeed be owned, that our hopes are sometimes disappointed, but our very disappointments frequently instruct ; and by missing truth in one path, we often find her more easily in another.

THIS method of proceeding by experiment has of late years opened a large field of knowledge, and the prospect wonderfully widens as we move forwards. Great discoveries have been made in this part of philosophy ;

D E D I C A T I O N. v

lofophy ; but perhaps as great, or greater, remain ftill behind : and there feems full room left for farther inquiries.

ELECTRICITY is a part of experimental philofophy, hitherto the leaft inquired into ; and however extenfive in itfelf (perhaps no property of matter more fo) has been fo little cultivated, that a fufficient number of facts have not yet appeared, upon which its laws may be eftablifhed. To investigate its laws, and from thence to deduce fome certain principles of fcience, is the intention of the following Treatife, which

vi DEDICATION.

lays before you a great variety of experiments, most of them new, and some surprizing.

As whatever tends to promote useful knowledge, tends to advance the happiness of mankind, any design of this nature, though imperfectly executed, cannot fail of meeting with your approbation. And besides, there is no person, to whom a treatise on this subject can with more justice be inscribed, than to him whose own researches, and whose encouragement and assistance to the late Mr. *Stephen Gray* gave rise to those extraordinary experiments, which have since ex-

cited

DEDICATION. vii

cited the curiosity of the Public to cultivate this part of philosophy. I am, with true respect and gratitude,

S I R,

Your much obliged,

and most obedient

humble servant,

BENJAMIN WILSON.

P R E F A C E.

ELECTRICAL experiments, and the cause of these wonderful effects, seem to have engaged, for some time past, the attention of the curious in several parts of the world, particularly in *England*.

WE are much indebted for the cultivation of this part of philosophy to Mr. *Stephen Gray*, and Professor *Muschenbroek*: the former made the capital experiment with the glass tube^a, and the latter that with the vial.

CONSIDERING the great variety of experiments which have been made

^a See the Philosophical Transactions of the Royal Society, Number 417.

in this part of philosophy, it has been very difficult to arrange them into any kind of order. And though my success herein has fallen very short of my wishes, yet I hope that all the defects of this work will be candidly overlooked and amended by some abler hand, who has more leisure and abilities.

I HAVE, in the conclusion of this Treatise, delivered my opinion of some of the latest writers on this subject. But since finishing this book, I have met with a piece published a few months ago at *Paris*, by *Monf. Jollabert*, professor of philosophy and mathematics, entitled, *Experiences sur l'Electricité avec quelques conjectures sur la cause de ses effets*, by which I find he looks upon electricity and the æther of *Sir Isaac Newton* to be one
and

and the same*. That I was of opinion that the most subtile and elastic

HYPOTHESE III.

* Je suppose d'abord un fluid très-délié, très-elastique, remplissant l'univers & les pores des corps même les plus denses ; tendant toujours à l'équilibre, ou à remplacer les vuides occasionnés. Je suppose encore que la densité de ce fluide n'est pas la même dans tous les corps ; qu'il est plus rare dans les corps denses, & plus dense dans les corps rares ; enforte que les interstices, que laissent entr'elles les particules de l'air, renferment un fluide plus dense que ne sont, par exemple, les pores du bois ou du metal.

HYPOTHESE IV.

C'EST au moyen d'un fluide que Newton a essayé d'expliquer divers phénomènes, tels que sont ceux de la lumière & de la pesanteur. Il estimoit, à la vérité, que ce fluide, par lui-même & sans avoir besoin d'aucune preparation, produit les différentes propriétés, de la lumière, de la gravité, &c. au lieu que, dans notre hypothese, il n'agit qu'après avoir été excité & mis en mouvement par quelque operation, telle qu'est le frottement &c. Cette différence dans la maniere d'agir n'empêche pas cependant que ce puisse être le même fluide, mais diversement modifié, qui produit ces phénomènes differens : &, si nous lui donnons ici le nom de *fluide électrique*, nous ne prétendons pas pour cela borner ses effets à ceux de l'électricité.

part of the electric matter is the same with the *æther* of Sir *Isaac Newton*, appears from an essay published in 1746. In the beginning of the year 1747, I made several new experiments, with farther observations, which I sent soon after to a merchant in *Holland*, who forwarded them to his correspondent at *Paris* for *Monf. Grand-jean de Fouchey*, the secretary of the Royal Academy of Sciences. I have been informed since, that the secretary never received them. The substance of those papers, together with some additions, make up the following Treatise, which is now offered to the public.

NOTE, The experiment in page 59, and one or two more of the following Treatise, were published in other words in the *Philosophical Transactions*, Number 485. But as they were
first

P R E F A C E. xiii

first made by me and Mr. *John Smeaton*, of whose name I have hereafter made mention, and I having occasion to relate them, they are there inserted. Thus much I thought proper to mention as an apology for a repetition of them.



A TREA-



A

T R E A T I S E

O N

E L E C T R I C I T Y.

P A R T I.

S E C T I O N I.

IN the making of electrical experiments the effects produced are so very different, according to the different methods of performing these experiments, that we must carefully attend to the most minute circumstances before we can hope to arrive at any certain knowledge of the laws by which electricity acts. To obtain this knowledge, the greatest electric effects seem most necessary. We shall therefore give an account of the several circumstances we have always observed requisite for producing them : and afterwards set down the

B

signs

signs by which bodies are known to be electrified; and how we are to judge of the different degrees of electrification. The machines, with which these kind of experiments are made, do not differ more in their construction than they do in their power of electrifying. It may not be improper therefore first to give a description of the machine with which the principal part of the following experiments was made.

A D H K represents a frame of wood two feet two inches long, and eighteen inches broad. The sides of this frame are three inches by one and a half; and the diameter of the wheel F G, which also is of wood, fifteen inches. The axis of the wheel, E E, is so contrived, that it can be taken out and the wheel separated from its axis, by which means they may be laid in the square A M M H; it being large enough to hold not only them, but other parts of the machine. G G represents a glass cylinder with metal ends twelve inches long, and five in diameter. P, a pulley three inches diameter, fixed to one of the metal ends: round this pulley and the wheel F G is a cord or string of catgut, which turns the cylinder round. The glass is rubbed by a cushion C, nine inches long and two broad, fixed to a spring S V, and made to press more or less against the cylinder by the screw y, passing through a cross-

cross-bar of wood d d, fixed upon the upper-part of the frame A M M H. p, represents a small pulley of brass to tighten or slacken the string, by moving it higher or lower : and it is prevented from slipping lower by a small screw h. The same pulley also serves to keep the string from rubbing against itself when crossed, by turning the stem of metal in which the pulley is fixed a little on one side. w w, are several straight wires of *equal* lengths ; one end of each is bent round, for the conveniency of hanging them on a thicker wire a a a. The wires may be raised or lowered by sliding it in the hole o, let into a bar of iron B B. This bar is supported by silk lines, L L L L, tied to the four pillars of wood 1, 2, 3, 4. The whole machine is fastened upon a table T T, by three hold-fasts with screws under the angles of the frame A D K.

As to the several circumstances that are necessary to be observed :

1. THE cylinder should be five inches in diameter at least, and about twelve inches long.

If the cylinder be eight or nine inches in diameter, all the following experiments may be made with it ; which is not the case with a less, for some experiments require a larger glass than others ; as will appear hereafter.

4 *A Treatise on Electricity.*

WE make use of a cylinder, because from glasses of that shape, or oblong spheroids, which approach nearer to cylinders than spheres, we have been able to produce the greatest effects. That cylinders or oblong spheroids are the most proper figures for this purpose, will be confirmed hereafter, not only from reason but experiments.

2. THE cylinder must be of an equal thickness, or nearly so, if it can be had; and rather *thin* than thick, and of a good polish.

3. IT must have no metal axis passing thro' it, unless the axis be covered with cement, wax, resin, pitch, glue, or some other unctuous matter which is not soft.

4. IT must be always freed from dirt and dust, as well as from moisture or dampness, before any experiment be made with it. To do the last more effectually, the loose dirt, and that which sometimes is found to stick very close to the glass, being first wiped off, take a piece of clean dry flannel, and hold it near a fire till it be well warmed, then turn the wheel and rub the glass all over from end to end very well with it.

5. THE cylinder must not be heated too much by continuing the friction of the cushion, but when an experiment has been made, let the turning of the wheel be discontinued for a little

little time, and the glass be rubbed again with the dry flannel, before a fresh experiment be made.

6. THE cylinder must be in the same good order for electrifying equally strong, before any experiment be begun to be made with it.

To do this more effectually the following farther cautions must be observed.

7. THE cushion C must be about three inches shorter than the cylinder is long.

8. THERE must be a piece of clean smooth leather (red was what I made use of) of a considerable length, and as broad as the cushion C is long; this leather must be moistened with a wet sponge from time to time on the rough side, and afterwards, the dry side must be warmed a little by the fire; when this has been done, and the dry side well wiped, to free it from dust and moisture (there being an oily matter brought out of the leather by heating it) place it between the cushion and cylinder, with the dry or smooth side to the glass.

N. B. IF the leather be gilt or covered over with silver, brass, or copper, and the metal side applied to the glass (the other side being also moistened with water) it will do full as well.

9. THE edges of this leather must not turn up towards the cylinder; this may be pre-

6 *A Treatise on Electricity.*

vented by rolling it up, or turning it back ; or letting a small weight hang to it.

10. DIFFERENT pressures of the cushion against the cylinder will produce very different effects, therefore the pressure should be *uniform*, and rather strong than otherwise.

11. THE wheel must be turned always the same way, so that the cylinder must turn towards the points of the wires ww, that is from C towards ww and m, and not from C towards m and ww. Those points ww must hang close to the glass, and about three and a half or four inches from the cushion.

12. THE wheel must be turned uniformly quick, and not faster in one experiment than another (suppose thirty or forty turns in a minute) unless where it is mentioned to the contrary.

13. THE bar BB must be an inch and an half or two inches in diameter, and the ends rounded off hemispherically, unless we mention the contrary.

14. THE silk lines LL, on which it hangs, must be of the thickest sort, and six inches long at least, and quite dry, and free from dust and dirt. As to the colour of the silk lines, let them be red or yellow.

15. METAL bodies, and such as will be particularized hereafter by the name of non-electrics,

ctrics, that are to be electrified, must be free from dust and dirt, and must have no edges, corners, or points ; nor must wires or strings be made use of (for they approach towards edges or points in some degree, by reason of their smallness) unless at any time we desire the contrary.

16. No points, corners, or edges, or small non-electric bodies must be any where near the body to be electrified, or the cylinder G ; except those points w w hanging to the side of the cylinder.

17. ALL non-electrics should be above eighteen inches at least, and points, corners, and edges, three feet at least, distant from the body to be electrified, or the cylinder G : unless they are placed on such bodies as will hereafter be distinguished by the name of electrics : and even then points, corners, and edges of non-electric bodies must be avoided, except the contrary be mentioned.

18. No flame, smoke, or steams, must be near the machine.

19. THE air must be dry, and freer from sulphur than it generally is, when the days or evenings are very warm.

20. THE top of the table on which the machine is fixed, as well as the machine itself, must also be freed from dust.

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21. THE table must stand on moist ground, or if the table be in a chamber, a wire passing from the machine to the moist ground will do full as well.

22. WHEN we mention *wax*, it is with indifference, for either glass, resin, pitch, glue, silk or hair, do as well.

23. COMMON bees wax of itself is too soft: therefore a quantity of resin (half as much, or more) should be dissolved in it, which will make the mixture, when cold, much harder and fitter for use.

24. WHEN either wax, resin, pitch, glue, glass, hair, or silk lines are made use of, we always suppose them very dry, and freed from dust and dirt; and the five first to be six inches thick, and the two last to be six inches long at least, unless the contrary be mentioned in any experiment.

25. WHEN a body is to approach, or be brought near an electrified body, we always suppose these three things to be carefully observed. First, that the approaching body be in contact with the earth at the same time. Secondly, that the approaching part be a rounded surface (a quarter of an inch at least in extent) free from points, corners, or edges. And lastly, that it be moved towards the electrified body, not slowly, but very quick: unless at
any

any time the contrary of any of these things be mentioned. If the electrified body be the approaching body, we suppose it to be moved towards the other also very quick.

26. BEFORE a fresh experiment be made with the same body, we always suppose no signs of its being electrified remaining.

27. IF a person should rub the glass with his hand instead of the cushion, we suppose it to be in the same place where the cushion is placed, and with the same pressure. With respect to the signs by which bodies are known to be electrified.

THE cylinder G, or bar BB (or any other body) is said to be electrified when light bodies of any kind are moved to and from any part of the cylinder or bar. And when two or more very light or flexible bodies of any kind, placed near one another, and in contact with any part of the cylinder or bar, are made to recede from one another by rubbing the glass only, the cylinder or bar is also electrified.

AGAIN, the bar is likewise said to be electrified when an explosion and painful sensation happens, on a person's approaching any part of it with any part of his body. Or when an explosion happens on the approach of any non-electric body towards the bar.

THE different methods to determine the degree of electrification under certain circumstances, as accurately as we are able, are as follow :

1. WHEN a body is electrified, observe the time it will take up before all signs of electrification cease : the longer the time is, the degree of electrification will be the greater.

2. WHEN a body is electrified, observe the distance at which light bodies are moved towards it, and at what distance it will electrify another body, the greatest distance is a sign of the greatest degree of electrification.

3. WHEN two light bodies are suspended in threads, and electrified, observe how far they will recede from one another : when they recede the farthest, the degree of electrification is the greatest.

4. WHEN a body is electrified, observe to what degree that body is capable of electrifying another body which is brought near it, both being suspended in silk lines, or laid on wax, resin, or glass : the more the first electrifies the other body, the degree of electrification in it will be the greater.

5. WHEN a body is electrified, and approached by another which is not electrified, to cause an explosion, approach it a second time, and repeat the approaches till no more

ex-

explosions ensue, observe their number, their degrees of *light* and *loudness* at each approach. The greatest number of explosions attended with the greatest degrees of light and loudness, are signs of the greatest degree of electrification.

6. WHEN a light is seen to issue from the body electrified, supposing the body somewhat pointed, and the room dark in which the experiment is made, and this light does not appear larger and brighter by continuing the electrification, that body is not capable of being electrified to a greater degree.

7. THE method commonly used to electrify bodies to the same degree, is to turn the wheel an equal number of times with the same velocity: the pressure of the cushion C being always supposed the same, and the glass in the same good order for electrifying equally well, as we have taken notice of before.

SECTION II.

EXPERIMENT I.

IF the cylinder of glass G (fig. 1.) be rubbed by the cushion C, the bar of iron BB with the wires ww, being suspended near the glass on silk lines LL, a person, upon approaching the bar BB with his hand, will perceive a luminous spark to issue, accompanied with a snapping noise, and a smart sensation; and light bodies, placed at small distances, will be moved to and from the bar.

It appears from this experiment that friction is necessary to cause these phænomena; for without rubbing, the cylinder will not produce these effects.

THE matter causing such effects we shall call *electric matter*: and the giving this property to bodies, *electrifying*.

THE luminous spark, whenever it is attended with a snapping noise, we shall call an *explosion*.

EXPERIMENT II.

WHEN the bar BB is electrified, and a finger or piece of metal moved towards it as was done in the ^{first} experiment, after an explosion the electric matter (or the greatest part of it) will be found to have deserted the bar; for a second

cond effect, equal to the first, cannot be produced till it is again electrified. Whereas if the bar, when electrified, be approached with glass, amber, wax, pitch, or glue, there will be no explosion; and the electric matter, or a considerable part of it, will be found to continue still in the bar; for if the finger or metal be applied immediately, there will be an explosion, and the same effects produced as at first.

EXPERIMENT III.

IF a person P stands upon glass, wax, resin, or glue R, and takes hold of the bar BB, upon being electrified, he will be found to retain the electric matter in like manner as the bar. If the person P stands on any of the same kind of bodies as wax, resin, glue, or glass, that are very thin, he will retain the electric matter in some degree, but not so strongly as in the other case. And if the person P does not stand upon any such bodies, but on the floor or earth E, and takes hold of the bar BB as before, neither he nor the bar, will appear to be electrified. fig. 2.

FROM the second and third experiments, it appears that the electric matter does not pass so readily through glass, amber, wax, resin, or glue, when such bodies are of a proper thickness, as when the same kind of bodies are thin: but the electric matter appears to pass through
metals

metals and animal bodies, of all magnitudes. And since in the latter part of the third experiment there is not the least appearance of electric matter within the person, or bar, and there is in the first part of the same experiment, the electric matter must be diffused and lost in the earth.

It also appears that metals, when rubbed in like manner as glass, cannot electrify any other body: for if we suppose that the electric matter was by friction brought to, or excited in them, yet it would immediately pass away by them.

EXPERIMENT IV.

IF the widest end of a small glass syphon be immersed in a metalline vessel filled with water, and suspended on the bar; on turning the wheel the water will be electrified, and during the turning of the wheel, the water will in running out at the narrower end of the syphon spread to a much greater distance than if the water was not electrified, or the turning of the wheel was discontinued. And if upon ceasing to turn the wheel, a non-electric body be brought towards the end of the syphon before the electric matter be intirely dissipated, the water will again spread, but not to so great a distance as when the wheel is continued turning.

EXPE-

EXPERIMENT V.

IF a person standing on wax, resin, glue, or glass, takes hold of, and thereby becomes as it were a part of the bar or body to be electrified; or if a large quantity of iron, lead, copper, or any other metal, be set upon any of the above bodies, wax, resin, glue, &c. in the place of the person, and communicates with the bar, upon electrification, the effects will be the same, whether you approach any part of that person, or the bar, or body electrified; that is, there will be an equal explosion from any part of the person or the metal. And if the person electrified approaches any part of his own body, or any other body that is *equally* electrified with himself, there will be no explosion.

It appears from the fourth and fifth experiments, that when a quantity of electric matter is communicated to any of those bodies (every part of which is supposed equally capable of receiving it) the same matter diffuses itself equally throughout that body, and is consequently *fluid*.

EXPERIMENT VI.

LET all the apparatus be placed upon cakes of wax, resin, glue, or glass, so that all communication between the earth and the apparatus be cut off, the bar BB will not be electri-

fied in so strong a manner, after a few turns of the wheel, as in the other experiments.

FROM this experiment it appears (since there is no other change of circumstances in making it, except that the communication between the machine and the earth is cut off) that the electric matter comes from the earth, and is collected, not produced by the apparatus.

THAT it is capable of passing through some bodies, and not through others.

THE former of these bodies are called *non-electric*, the latter *electric* bodies.

IT seems upon the whole of this section, as if the electric fluid were diffused throughout all bodies (at least non-electrics) on, or near the surface of the *earth*, as well as the body of the earth itself.

SECTION III.

WHEN bodies are electrified, we suppose they have received an additional quantity of electric matter, and in such circumstances the electric matter may be said to be *accumulated*.

EXPERIMENT VII.

WHEN two threads of equal lengths are hung close together, and so as to touch the
body

body to be electrified, they will recede further and further from each other, as the body is higher and higher electrified. And the higher the body is electrified, the longer it will be before all the electric matter be dissipated and lost.

IF the electric matter passed out of the threads as fast as it entered them, the threads could not recede from one another more or less, as they are more or less electrified; so that something must in part obstruct or hinder its passing out: and if the electric matter passes faster in than it does out, which is here the case, there must be an accumulation; therefore the distance of the threads will be greater or less, as the accumulation of the electric matter is more or less increased: and if it be more or less increased in the threads, it must also be so in the bar. The truth of this is manifest from the effects.

EXPERIMENT VIII.

IF a sphere of iron three feet in diameter, and a sphere of the same metal three inches in diameter, be placed upon separate bodies of wax, and electrified at the same time by the bar BB, light bodies will not be moved towards the larger sphere from a greater distance than towards the lesser sphere. But if whilst they are electrified, both of them be immediately re-

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moved

moved at the same time from the bar, the larger sphere will retain its electric matter longer than the lesser sphere.

FROM the latter part of experiment the fifth it appears, that non-electric bodies of the same kind are equally electrified, when they are in contact with the electrifying body. Therefore the two spheres in the above experiment are equally electrified. The quantities of matter in these spheres are very different, and the times of continuing longer electrified are likewise different; consequently the quantity of electric matter contained in each must be different. But the power of moving light bodies to and from them, is the same in both bodies whilst they are in contact with the bar, or at the instant of removing them from the bar; and of consequence does not depend upon the quantity of electric matter; but will be always the same, supposing the fluid collected equally dense. This is the case with water and air (provided the density of the air be the same in different spaces) wherein the resistance made to a body falling will be the same, whether the quantity of water or air be greater or less. But the effects of moving of light bodies, and of continuing longer electrified (as well as the magnitude of the explosion) however, will be different, as the quantity of electric matter in
any

any given quantity of matter differs: or, in others words, will be in proportion to the different density of electric matter, by experiment 7. Since then, this fluid is capable of being made more or less dense, as a greater or less quantity may be included in the same space, it is therefore *elastic*: and since it is elastic, the more it is compressed, with the greater force it will restore itself: and consequently with the greater velocity.

EXPERIMENT IX.

IF two bodies x and y (fig. 4.)^a of equal or unequal magnitudes, but equal densities, suppose two globes of iron, the first electrified, the other not, are placed or suspended at a given distance from each other upon electric bodies, or silk lines L L, and afterwards x be made to approach y, or y x, the quantity of electric matter will be lessened in x, and that in a different proportion as the bulk of the body y is greater or less.

For if x be electrified, and of equal magnitude and density with y, and the former be brought near the latter, the effects of the one and the other will be found equal: if y is greater than x, their effects will be still equal, but weaker, than in the other case: because of

^a Mr. *Watson* published an experiment of this kind in his *first Essay on Electricity*.

the electric matter being expanded in a larger space, or a larger quantity of matter. And therefore if *y* was a sphere of one thousand feet in diameter or more, and *x* one foot only, the effects would become insensible: even tho' the whole quantity that was accumulated in *x* should be diffused in *y*: as may be gathered from comparing the cubes of those diameters.

COROLLARY.

HENCE it follows, that the elasticity of the electric fluid is lessened in proportion as it is rarified. And hence also, we may easily conceive how the *earth* may constantly have this matter diffused *every where within it*, and yet the effect not sensible, till it is collected in greater quantities in any particular body.

EXPERIMENT X.

IF a long wire be extended, and suspended in silk strings, that are tied to stakes fixed in the ground (to prevent the wire from being near the earth or other non-electrics) and afterwards be electrified: the longer the wire is, the greater will be the effect, or painful sensation, upon causing an explosion, by a person's approaching the wire.

IT has been already shewn (by experiment eighth) that effects apparently equal (such as moving of light bodies from certain distances, and repelling them again) will always be produced

duced by unequal quantities of the electric fluid, provided the densities of the fluid be the same. But when the density of the one exceeds the density of the other, the difference of the effects are as that excess (by experiment seventh) the greater then the excess of density is, with the greater force, or velocity, it must endeavour to restore itself; consequently the greater will be the effect or painful sensation.

BUT, *cæteris paribus*, the longest electrified body gives the greatest effect, such as the explosion or painful sensation; therefore the electric matter must move with a greater velocity through a long body electrified, than through one that is shorter. For if the same wire be twisted in a heap together very close, the sensation and explosion will be *much* weaker.

EXPERIMENT XI.

IF the electric matter be communicated to a wire (suspended as in the last experiment) two or three miles in length (and it is not easy to make the experiment with a greater length) the effect will be perceived at the further end from the machine (by moving too and fro light bodies placed near that end) as soon to all appearance, as at the end nearest the machine: and if both ends of the wire be approached as near as possible at the same time, the electric matter will be only seen to issue from one of

them, viz. from that which is soonest approached.

QUERY I. Whether such propagation may not be owing to the elasticity of the electric matter? If so, the elasticity thereof, in proportion to the quantity of matter it contains, must be vastly greater, than that of any other elastic body or fluid we are acquainted with.

S E C T I O N IV.

PROPOSITION I.

IF the surface of a non-electric C (pl. I. fig. I.) be applied to the surface of an electric body G, and the one be agitated by the motion of the other, a quantity of electric matter contained in one or the other, or both of them, will be excited: which quantity will be conveyed to the next adjacent non-electric body whose parts are not agitated, where it will be continually diffipated; unless the adjacent body be separated from other non-electrics by the interposition of electrics, in which case the electric matter will be retained, and accumulated therein.

THE cushion, in this proposition, is the non-electric represented by C; G is the glass cylinder, or the electric body; from the action
of

of those two, the electric matter is produced by their rubbing or pressing against each other, the glass *G* being turned swiftly round: *BB* is the bar of iron (including the wires *ww*) which is the adjacent non-electric body not agitated, and *LL* are the silk lines, or the interposed electrics, to prevent the electric matter from dissipating by them.

THE truth of this proportion will appear from the first experiment, as well as from all the methods hitherto found out of accumulating the electric matter in non-electric bodies.

IF the proposition be not sufficiently proved,

TURN the wheel the contrary way, so that the rubbed parts of the glass cylinder may pass by the edge of the frame of the machine *m*, before they come to the wires *ww*; and the bar will appear to be electrified in a less degree. Lay a number of wires, such as these marked *ww* (that hang against the cylinder) on the frame with the points or ends towards the glass, then continue to turn the wheel still the same way, and the bar will appear to be electrified in a much less degree. But turn the wheel the other way and the bar will appear to be as strongly electrified, as in experiment first, section second.

PROPOSITION II.

SUPPOSING the bodies to be in other respects, as in proposition first, but the adjacent non-electric one BB, which is there not agitated, to be put into an equal agitation with the other two, C and G; in that case, the adjacent non-electric body BB will appear to be but little, or not at all electrified.

EXPERIMENT.

LET ^a the glass cylinder G (fig. 1.) (which in this experiment we suppose ten inches at least in diameter) be excited to electricity by means of C, or by a person standing on the floor, applying his hand to one side of it; whilst another person standing on wax, or resin, applies his hand in the place of the iron bar BB or the wires ww (they being taken away) and rubs that opposite side of the glass, in the opposite part g, at the same time, with a pressure against G as nearly equal to the pressure of C as can be judged; in such circumstances, the person standing on the wax will be but little, if at all electrified; but let him apply his hand to the glass *lightly*, or the ends of his fingers only, and he will then, without any other alteration, be strongly electrified.

^a This experiment was made by Mr. John Smeaton, the inventor of the new air pump.

PROPOSITION III.

WHEN a body has *lost* any part of its original quantity of electric matter, or has *gained* an equal part, over and above what it originally had, in both these cases the electric effects, such as the explosion, and the motion of light bodies towards it, will be the same. In the first case, these effects are produced by its gaining a quantity equal to that which it had lost, and in the second case, by its losing a quantity equal to that which it had gained.

EXPERIMENT.

LET the person who turns the wheel and the machine itself M (fig. 2.) be placed upon electrics at some distance from all other non-electric bodies, excepting the suspended bar B B, including the wires w w, which bar in this case must have a free communication with the earth, by letting some non-electric N touch it and the earth. Then if after a few turns of the wheel, the wheel being still continued turning, another person approaches any part of the frame of the machine M, or the person who turns the wheel, an explosion will be perceived in like manner as if the same were electrified; and light bodies, placed at certain distances from the machine or the person

son turning the wheel, will also be moved towards them.

Now if, in this experiment, the machine and person have really lost part of their original quantity of electric matter, and any of the bodies in the first, third, fourth, fifth, seventh, eighth, ninth or tenth experiments, have really gained an equal part over and above what they originally had, then the proposition is true. For whenever the *equilibrium* in air is destroyed by any part of it being rarefied or condensed equally, that *equilibrium* will be soon regained. Now what is true of air, which is an elastic fluid, may be supposed to hold good in regard to the electric matter, which seems to be a fluid similar to air as to its elasticity.

PROPOSITION IV.

NON-ELECTRIC bodies, under certain circumstances, actually lose part of their original quantity of electric matter.

EXPERIMENT.

LET the whole apparatus be placed as in the last experiment, except the bar BB (fig.2.) which is now to have no communication with the earth (the non-electric N being taken away) when the bar has been electrified, and the matter discharged by two or three explosions, it cannot be electrified afresh to an
equal

equal degree, without opening a communication between the earth and the machine M, or setting another quantity of non-electric matter ^a which is not electrified, upon the machine M, or ceasing to turn the wheel for a time. The machine then must have lost some part of its original quantity of electric matter, as it no longer retains a power of electrifying the suspended bar. But let the suspended bar BB be held by the hands of one, two, three, or more persons standing upon wax, or let there be other large quantities of non-electric matter 1, 2, 3, and placed in the same circumstances, and the machine M will appear to have lost a yet greater quantity; which loss will appear to increase as the numbers increase in arithmetical proportion, to a limited degree, or in other words, as the quantities of non-electric matter added are greater, to a limited degree.

ONE of these suppositions must be true, viz. that the machine is electrified in like manner as the suspended bar, and receives the electric matter from without; or else such matter is contained in the machine itself, and excited into action by means of friction. Now if the machine receive the electric matter from with-

^a The non-electric matter to be set upon the machine, must be brought to it by means of electric bodies.

out, it must be either from the surrounding atmosphere or the earth. The first cannot be the case, for supposing it was, the effects produced would be the same how ever the machine was placed ; upon condition only that it was placed in the open air : nor can the latter be true, since by supposition, in the preceding proposition, all communication is intercepted between the earth and the machine, the electric matter then must be contained in the bodies themselves. And that part of this accumulated electric matter in the bar is dissipated upon an explosion is manifest, since after two or three explosions made, it is not in our power in the circumstances described in the above experiments (how long soever the same friction be continued) to cause an equal number of explosions equally strong from the bar afresh : and therefore we may conclude, that it does not issue from the glass but from the machine itself ; for if that was supposed, an open communication between the earth and machine ought to make no difference.

WHEN the machine and person turning the wheel cease to electrify the suspended bar of iron BB, some gentlemen have thought the machine itself and person turning it may be electrified, and by virtue of the whole being in a repulsive state, the electric matter cannot

not pass out of them into the bar : but this supposition does not appear to be true, as may be gathered further from the following experiments.

EXPERIMENT I.

LET two pieces of thistle-down be tied to separate threads two or three inches long, and those threads be afterwards tied to one end of a silk string fifteen or twenty inches long, upon bringing them towards the bar, whilst the wheel is continued turning, and the machine in contact with the earth, the fibres of the down will stand at a distance from each other, and from the bar, and be stretched out in many directions : whence we may safely conclude, that the quantity of electric matter surrounding any part of bodies electrified to some distances, causes the parts which are free and at liberty (and such are the pieces of down and their fibres) to recede from one another and the bar ; in like manner as the threads in the seventh experiment, section third. If any non-electric body be held near the pieces of down whilst they are in the above circumstances they will be moved towards the non-electric, and immediately after towards the bar, then back again, and so on continually, and very quick, whilst the bar is continued to be electrified.

EXPERIMENT II.

ON the contrary, instead of holding the pieces down towards the bar, let them be held towards the frame of the machine or the person who turns the wheel (the machine and person turning the wheel, being now set upon wax) and one of the pieces of down will be moved towards that part of the person or the frame of the machine it is nearest to; and the down will continue to touch it, whilst the other piece will be stretched out towards the nearest non-electric, which is in contact with the earth. And if a non-electric body be brought in like manner equally near the last mentioned piece as in the other experiment, there will be no such appearance as that of their being moved too and fro between the bar and the non-electric body. But on the contrary, the pieces of down will be extended between the non-electric and the bar, and continue so, whilst the wheel is continued turning.

EXPERIMENT III.

AGAIN, if the machine and person be electrified in like manner as the bar (by another machine) upon holding the pieces of down as in the second experiment, they will be moved too and fro between the machine and the non-electric, in like manner as they were between the bar and the non-electric in the first

experiment. If a non-electric approach any part of the frame of the machine, as in the second experiment there will issue an explosion equal (if not greater) to that when the same body approaches the machine in like manner as in the third experiment, or the bar in the first experiment. Now since nearly similar effects, with respect to the explosion, are produced in the first, second, and third experiments, and at the same time quite opposite effects, with respect to the repulsive power; there being no signs of the electric matter being accumulated either in the machine, person, or the pieces of down in the second experiment; the machine and person in the second experiment, are neither of them electrified: or in other words, the machine and person have not received a greater quantity of electric matter than originally belonged to them, but on the contrary have lost part of their original quantity of electric matter.

N.B. WHEN a body has lost any part of its original quantity of electric matter, in such circumstances the electric matter in that body may be said to be *attenuated*.

COROLLARY I.

FROM hence it follows, that a free communication with the earth is necessary to cause and continue an accumulation of electric matter

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ter in non-electric bodies ; friction alone not being sufficient.

COROLLARY II.

HENCE also the explosion and sensation will be greater when a person electrified touches any body whose original quantity of electric matter is made less or attenuated, than when the same person touches any body whose original quantity is neither attenuated, or made greater : which effect is quite opposite to that mentioned in the latter part of the fifth experiment, section second.

PROPOSITION V.

THE original quantity of electric matter in a non-electric body, in certain circumstances, cannot be *attenuated*, or made less in that body, beyond a certain degree.

EXPERIMENT.

LET every circumstance be the same in this experiment as it was in the experiment following the third proposition, and then cause the wheel to be turned as before, after a number of turns of the wheel (suppose forty) light bodies will be moved towards the machine from a certain distance : and if any part of the machine be approached by a non-electric, there will ensue a certain explosion : continue the friction for any length of time, and these ef-

fects will not differ ; that is, light bodies will not be moved from greater distances, nor will the explosion be larger.

PROPOSITION VI.

THE electric matter cannot be *accumulated* in a non-electric body beyond a certain degree, in certain circumstances.

EXPERIMENT.

LET the bar BB, or any other non-electric body, placed on wax, or resin, or suspended by silk lines, be electrified by a few turns of the wheel ; and a light body will be moved towards it from a certain distance, and if two threads are electrified, as in the seventh experiment, section 3, they will recede from one another to a certain distance ; continue the electrification for any length of time, and there will be no apparent difference : that is, a light body will not appear to be moved towards the bar from a greater distance, nor will the threads appear to recede further from one another, neither will the explosion be any larger when the bar is approached by a non-electric.

SECTION V.

PROPOSITION. VII.

THE accumulation of electric matter in a non-electric body, in *some* circumstances, seems to be directly proportional, and in *other* circumstances reciprocally proportional, to the resistance it meets with as it tends to expand and dissipate; provided that in each case the resistance does not exceed a certain degree.

EXPERIMENT I.

WHILST the wheel is turning, and the bar BB (which is now supposed pointed at each end) constantly electrified, a light will be seen to issue from the extremities thereof; and if one of the extremities has a finer point than the other, the light will issue most copiously from that point; but there will be no such appearance in any part of the surface of the bar: nor will the bar be electrified to a greater degree, though the friction be continued ever so long. On ceasing to electrify the bar, that instant (to all appearance) the light at the point ceases; and if a person brings a non-electric near the point, the light will again issue for a very short time, after which there will be no appearance of electric matter remaining in the bar.

EXPE-

EXPERIMENT II.

IF the bar be cylindrical, and an inch and an half, or two inches in diameter (which we have supposed all along) and have one of its ends rounded evenly off, on electrifying it, there will issue a light from that end only which is pointed, and the bar will be somewhat more strongly electrified.

EXPERIMENT III.

IF the pointed end of the bar be also rounded evenly off, in like manner as the other end, there will be no appearance of light either from the surface or those rounded extremities; and if the wheel cease from turning, the bar will continue longer electrified, than in either of the two last experiments: so likewise the explosion will be larger, and louder; and consequently, the bar will be more strongly electrified, than in either of the two last experiments: which degree of electrification can never be made greater by continuing the turning of the wheel.

OBSERV. I. From these three last experiments it appears, that points resist the exit of the electric matter less, than surfaces; and that the bar, in the several circumstances mentioned in those three experiments, is not capable of receiving a greater quantity of electric mat-

ter, than what is produced by a few turns of the wheel.

EXPERIMENT IV.

IF the finest pointed needle that can be had (or any other angular termination, or edge of a non-electric body equally fine) be held at some distance, suppose eighteen inches, or thereabouts, from the bar, by a person standing upon the earth with the point towards the bar, whilst the bar is electrifying, light bodies will not be moved from so great distances towards the bar, nor will the explosion be so great on a person's touching the bar with his finger, as when the needle is taken away.

EXPERIMENT V.

MOVE the point of the needle nearer the bar (the electrification being continued) and these effects will be more apparent; that is, light bodies will not be moved from so great distances, nor will the explosion be so large as in the last experiment.

EXPERIMENT VI.

IF the point of the needle touches the bar, light bodies will not appear to be moved towards the bar, though placed very near the bar. And if the bar be approached by a piece of metal, or the finger of a person, no explosion will ensue.

OBSERV.

OBSERV. II. From the fourth, fifth, and sixth experiments it appears, that the electric matter dissipates faster, the nearer pointed bodies (or other edges or angular terminations of non-electric bodies equally fine) are brought to bodies electrified.

EXPERIMENT VII.

IF instead of the needle point, the end of a body which has no point, or sharp edge, suppose the head of the needle, or the end of a thick wire, evenly rounded off, be opposed towards the bar at the same distance the point was opposed in experiment the fourth, light bodies will be moved towards the bar from much greater distances than those mentioned in that experiment: and the explosions from the bar will also be greater.

EXPERIMENT VIII.

MovE the end of the wire, or the thick end of the needle, considerably nearer the bar, and then the effects will be nearly the same with those mentioned in the fourth experiment.

EXPERIMENT IX.

IF the end of the wire, or the thick end of the needle be still moved nearer, till it be in contact with the bar, the effects to appearance will be the same with those mentioned in the sixth experiment.

OBSERV. III. From the seventh and eighth experiments, compared with the fourth and fifth experiments, it appears that the electric matter in the bar is dissipated faster by the approach of bodies finely pointed, than of bodies that are rounded off, or have not points equally fine when opposed at equal distances. But when either kind of bodies is in contact with the bar, the effects are the same.

EXPERIMENT X.

IF a much larger surface than the end of the wire, or the edge or angular termination of any other non-electric body, equally blunt, be opposed at the same distance from the bar as mentioned in the fourth experiment (suppose the head of an iron poker) which is round and large, on electrifying the bar again, the explosion from the bar, on a person's approaching it with a piece of metal, or his finger, will, to all appearance, be the same as when when the poker is taken away intirely; so also light bodies will be moved from equal distances, whether the poker be held there or not; nor will there be any difference if the palm, or back of a person's hand, or any other larger surface be opposed at the same distance.

EXPERIMENT XI.

MovE the end of the poker, or the surface of the hand, half way nearer towards the bar,
tha

that is, about nine inches, and the difference, whatever it may be, will not be perceivable.

EXPERIMENT XII.

BUT move either of them considerably nearer the bar; and there will be a difference; which difference (at a proper distance) will be the same nearly with that mentioned in the fourth experiment.

EXPERIMENT XIII.

IF either of them be in contact with the bar, the effect to appearance will be the same with those mentioned in the sixth and ninth experiments.

OBSERV. IV. From the tenth, eleventh, and twelfth experiments, and the fourth, fifth, seventh and eighth experiments, it appears that the electric matter in the bar is not dissipated so fast by opposing large surfaces at some distance from the bar, as by opposing lesser surfaces at the same distance. And from the sixth, ninth, and thirteenth experiments it appears, that the electric matter in the bar is dissipated equally fast (to appearance) in each experiment when the bodies are in contact with the bar.

EXPERIMENT XIV.

IF the person holding the needle (or any other angular termination, or edge of a non-electric body equally fine) stands now upon a thick cake of wax, with the point of the needle

dle towards the bar, at the same distance with that mentioned in the fourth experiment; on electrifying the bar, the person holding the needle will be electrified also, but not to an equal degree with the bar; as appears from another person's approaching each of them separately with his finger: there issuing a larger explosion from the bar, than from the person who stands on the wax.

EXPERIMENT XV.

IF the point be moved nearer the bar, the person then will be more strongly electrified, but not yet to an equal degree with the bar.

EXPERIMENT XVI.

IF the point be in contact with the bar, then the bar, needle, and person, will all appear equally electrified.

OBSERV. V. From the fourteenth, fifteenth, and sixteenth experiments, it appears that the electric matter passes by the needle into the person holding it: consequently, if the person did not stand on wax, the electric matter would pass, and be dissipated in the earth by experiment third, section second, as well as by the sixth, ninth, and thirteenth experiments in this proposition.

EXPERIMENT XVII.

IF instead of the point the person turns the thick end of the needle, or wire, towards the
bar,

bar, but at an equal distance from it with that mentioned in the fourth or fourteenth experiments, he will not be sensibly electrified.

EXPERIMENT XVIII.

MOVE either of them considerably nearer the bar, and he will be electrified in a small degree.

EXPERIMENT XIX.

LET the thick end of the needle or wire be in contact with the bar, and the bar, wire, and person, will appear equally electrified, and to the same degree with the sixteenth experiment.

EXPERIMENT XX.

IF, instead of the wire, the poker be opposed at the same distance as mentioned in the fourth or fourteenth experiments, the person holding it will not be electrified.

EXPERIMENT XXI.

LET him move it half way towards the bar, that is, nine inches, still there will be no appearance of electric matter in the person.

EXPERIMENT XXII.

IF he moves it nearer the bar, he will be electrified, but in a less degree than the bar.

EXPERIMENT XXIII.

IF the poker be in contact with the bar, the bar, poker, and person holding it, will be equally electrified; which in this respect is the
same

same with the sixteenth and nineteenth experiments.

OBSERV. VI. From these last experiments it appears, that large surfaces resist the *entrance*, as well as the *exit* of the electric matter more, than lesser surfaces; such as points, edges, and angular terminations. And therefore from the whole of these experiments it seems, that the accumulation of electric matter in bodies, in certain circumstances, is directly proportional to the resistance it meets with as it tends to dissipate.

WE are now to shew, that in other circumstances the accumulation of electric matter is reciprocally proportional to the resistance it meets with as it tends to dissipate.

EXPERIMENT XXIV.

TAKE a clean dry thin vial V (fig. 5.) which will hold about a pint, or more, and fill it with filings of iron, or water; then put a cork into the neck of it, and push a thick wire w thro' the cork into the vial amongst the filings (if water be made use of the wire must touch it) and bend the outer part of the wire w, so that it may be hung upon any thing as occasion may require. This being done, hang it on the bar BB, and let nothing touch the outside of the vial: then, electrify the bar for any time, suppose forty turns of the wheel; after which, stop the

the wheel, and take the vial off from the bar, and set it on wax: or, which amounts to the same, let the vial be taken off from the bar very quick whilst the wheel is turning, and immediately set upon wax as in the other case; and the filings, or water, will (to all appearance) be no more electrified than the bar itself. This is known from the various methods of determining the degree of electrification described in the first section, as

1. THE explosions from the wire w upon a person's approaching it for any number of times, will never exceed the explosions from the bar B B, when approached in the same manner.

2. IF the wire w be held for any time by a person standing on wax (when the vial is taken off from the bar) he will be electrified in so small a degree as scarce to be perceived. The same thing happens, nearly, if the bar be held in like manner by the person, the turning of the wheel being discontinued.

3. IF the room be dark (which we suppose the case whilst all the experiments are made that belong to this seventh proposition) and the end of the wire w approached by a non-electric, a very faint light will appear to issue from it for a very short time. The like effect will appear from the bar B B, provided one end thereof

thereof be as small as the end of the wire, and shaped also like it.

LASTLY, If a non-electric body be brought near either to the wire, or the bar, all signs of their being electrified will presently disappear, and nearly in the same time.

EXPERIMENT XXV.

HANG the vial again upon the bar, and let a person standing on the earth, take hold of the outside of the vial, and electrify again by turning the wheel an equal number of times: then stop the wheel, and take the vial off, and set it on wax as before: or let the vial be taken off from the bar very quick (whilst the wheel continues turning) and set upon wax; the filings within the vial will be electrified to a much greater degree than in the last experiment. But the bar will be electrified in no greater degree than it was in the first experiment. The difference between this, and the first experiment may be determined by any of the same methods. For example,

IF the first method be made choice of, there will issue a large number of explosions from the wire w, and only two or three at most from the bar.

IF the second be tried, not only one person, but several persons will be electrified, and that in a very sensible degree: provided they all

stand on wax, and hold one another, and any one of them the wire *w*: which is far from being the case, if the bar in this experiment be held in like manner.

IF the third method be made use of, a larger quantity of light will appear to issue from the wire *w*, and for a longer time than appears to issue in the first experiment: but the light from the bar in this, is the same with that in the first experiment.

AND if the fourth method be tried, equal differences appear, for the bar will lose all signs of being electrified in the same time (to all appearance) it did in the first experiment: but the vial will take up a much larger time before the filings and the wire *w* have lost all signs of being electrified.

THERE are two other remarkable experiments that also prove the accumulation of electric matter to be greater in one case than in the other. They are performed with the same vial, but filled with water. The vial is to be without a cork; so that it may be electrified by a wire hanging upon the bar *BB*.

EXPERIMENT XXVI.

^a IF the vial be brought so near to the wire, by a person standing on the earth, that the

^a This Experiment was first made by Dr. Bevis.

end thereof touches the water in the vial, and the wheel be turned an equal number of times with the first or second experiment, and the vial afterwards taken away from the wire ; on pouring only *part* of the water into a metal dish, which must be held by a person standing on wax ; the person will be so strongly electrified, that if in his other hand he holds a metal spoon with a little warm spirit of wine, on the approach of a non-electric towards the spirit, it will immediately be seen to flame.

EXPERIMENT XXVII.

IF the vial be filled again with water, and set upon wax, on electrifying it as in the first experiment, and ceasing to turn the wheel, the water will not be electrified to that degree it was in the third experiment, as may be readily found upon making the same trial ; for the person will not be so much as sensibly electrified ; even though the whole quantity of water be poured into the metal dish.

HENCE it appears that the accumulation of electric matter is greater in the 25th and 26th experiments than in the 24th and 27th. Now if it shall appear that the resistance is less in the 25th and 26th than in the 24th and 27th experiments, we may conclude that in certain circumstances the accumulation of electric matter is reciprocally proportional to the resistance

sistance it meets with as it tends to expand and dissipate.

THAT the resistance given to the exit of the electric matter is greater in the 25th and 26th experiments than in the 24th and 27th, will appear from the following experiments and observations.

EXPERIMENT XXVIII.

IF the vial V be hung upon the bar BB (fig. 5.) and nothing touch the outside of the vial, electrify the bar again, and a light will be seen to issue from the end of the wire w after the first turn of the wheel, or rather before one turn is made; and light bodies will be moved towards the outside of the vial in like manner as towards the bar, but not at so great a distance as they are towards the bar. Continue the turning of the wheel, and these effects will not be greater nor will the electric matter be accumulated to a greater degree within the vial, than is mentioned in the 24th experiment.

OBSERV. VII. From this experiment it appears that the electric matter cannot be accumulated to a greater degree in the vial in these circumstances: and that less electric matter passes from the sides of the vial than from the bar. And therefore the resistance is greater from the vial than the bar.

EXPERIMENT XXIX.

IF a person holds the point of the fine needle (or any other angular termination or edge of a non-electric body equally fine) towards the outside of the vial V, and at the same distance from it with that in the fourth experiment from the bar, the filings in the vial will be electrified to a much greater degree than the bar, but weaker than that mentioned in the 25th experiment: after which, if the vial be not taken off, and the wheel be continued turning for any time, a light will be seen to issue from the wire w, in like manner as in the 28th experiment. But the filings will be electrified in no greater degree in such circumstances than is mentioned in this experiment.

EXPERIMENT XXX.

MovE the point nearer, and the filings in the vial will be more strongly electrified; and the light at the end of the wire w, will be something longer, as to time, before it can be seen to issue.

EXPERIMENT XXXI.

LET the point of the needle be in contact with the vial, and the filings will be as strongly electrified as in the 25th experiment, and the time also before the light can be seen to issue
from

from the wire w, will be as long as it was in that experiment.

OBSERV. VIII. From the xxixth xxxth and xxxith experiments, it appears that more electric matter passes into the vial than passes out from its sides in any instant : and that there are three different degrees of accumulation of electric matter in the filings, which are owing to the different degrees of resistance ; the greatest accumulation being caused by the least resistance.

EXPERIMENT XXXII.

IF instead of the point the thick end of the needle, or wire, be opposed towards the vial at the same distance with the ivth or xxixth experiment, the filings will only be electrified to an equal degree with the bar ; or in other words, the bar and filings would be just as much and no more electrified, to all appearance, than if no such body had been opposed at that distance : so that the effects, with respect to the explosions from each, and the light from the wire w, are the same as those mentioned in the xxivth and xxvth experiments.

EXPERIMENT XXXIII.

MovE the thick end considerably nearer the vial, and there will be a difference ; for the effects now will be nearly the same with those mentioned in the xxixth experiment.

EXPERIMENT XXXIV.

IF the thick end be in contact with the vial, there will be a greater difference: for the filings will be more strongly electrified, and to all appearance in the same degree with the xxvth and xxxist experiments

OBSERV. IX. From the xxxii^d and xxxiii^d experiments it appears, that at equal distances with those mentioned in the xxixth and xxxth experiments there are different effects caused by the different degrees of resistance.

EXPERIMENT XXXV.

IF, instead of the needle or wire, the rounded end of the poker, or the palm or back of the hand, be held towards the vial at the same distance with the fourth experiment, the filings will not be electrified more than the bar. And the light will appear at the end of the wire w, about the same time it did in the xxviiith experiment.

EXPERIMENT XXXVI.

MOVE the poker or hand half as near again, that is about nine inches, and there will be (to all appearance) no difference.

EXPERIMENT XXXVII.

BUT move it nearer, and there will; for the filings will be more strongly electrified than the bar: besides, there will be a small interval
of

of time before the light appears at the end of the wire w.

EXPERIMENT XXXVIII.

ON bringing the poker or hand in contact with the vial, the filings will appear to be electrified to as great degree as they were in the xxvth xxxist and xxxivth experiments, and the light, before it is seen to issue from the wire w, will be much about the same time it was in those experiments.

OBSERV. X. From the xxxvith and xxxviith experiments it appears, that at equal distances with those mentioned in the xxixth xxxth and xxxii^d experiments, there are other degrees of resistance caused, and different degrees of electric matter accumulated.

EXPERIMENT XXXIX.

IF the person, instead of standing on the earth, now stands on *wax*, as in experiment xiv. and opposes the point of the needle towards the vial at the same distance as was done in the ivth and xxixth experiments, the person will be electrified in a small degree weaker than the bar; and the filings will be electrified in a small degree greater than the bar: so that the accumulation of electric matter in the filings will be considerably less than the accumulation in experiment xxix. And if the vial in this experiment be not taken off, and the wheel

be continued turning for any time, a light will be seen to issue from the wire w, in like manner as in the xxviiith experiment, but not so soon as in that experiment, yet sooner than in the xxixth experiment.

EXPERIMENT XL.

MOVE the point considerably nearer, and the person will be more strongly electrified, so will the filings in the vial: and there will, after a shorter time than in the xxixth experiment or xxxth, issue a light from the end of the wire w. The degree of accumulation of electric matter in the filings in this experiment is less than the degree mentioned in experiment xxx.

EXPERIMENT XLI.

MOVE the point, so as to be in contact with the vial, and the electric matter will be accumulated in the filings to a much greater degree, but still less than in experiments xxv. or xxxi. In this case it will take up a longer time before the issuing of the light from the end of the wire w can be seen than it did in the last experiment; but lesser than is mentioned in experiments xxv. or xxxi.

EXPERIMENT XLII.

IF the thick end of the needle or wire be opposed at the same distance from the vial as in the xxxixth and xlth experiments, the differences of electric matter accumulated will be
pro-

proportional ; but less than in those two experiments. And if the wire be in contact with the vial, the accumulation will be the same as in experiment xli. The difference of time at which the stream of light begins to appear at the end of the wire *w* in each experiment will also be proportional.

EXPERIMENT XLIII.

IF the rounded head of the poker or the palm or back of the hand be opposed in like manner at the same distances from the vial as in the xxxixth and xlth experiments, the differences of electric matter accumulated in each experiment will likewise be proportional, but less than experiment xlii. excepting when the poker or hand are in contact with the vial, for then the accumulation appears to be the same with the experiments xl. and xli.

OBSERV. XI. From these last experiments it appears, that at equal distances with the xxixth, xxxth and xxxist experiments, lesser degrees of electric matter are accumulated by increasing the resistance, than were accumulated in the xxixth xxxth and xxxist experiments, where the resistance was less. It also appears, that the accumulation of electric matter is the same, whether a small or large surface be in contact with the outside of the vial.

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EXPERIMENT XLIV.

IF more persons stand also upon wax, and communicate with the person who holds the needle, wire, or poker towards the vial at the distances mentioned in the preceding experiments, the filings will be more strongly electrified at those respective distances, than they were in these experiments: and still more so to a limited degree, as the persons added are more in number. And in each experiment it will be a longer time before the light appears at the wire w.

EXPERIMENT XLV.

THE like difference in proportion will happen when the thick end of the needle or wire is opposed (the same persons continuing on wax) at the like different distances.

EXPERIMENT XLVI.

THE same will happen in proportion when the rounded head of the poker is opposed (the same person continuing on wax) at the like different distances also.

OBSERV. XII. From these experiments it appears, that the accumulation is made greater by making the resistance less than it was in experiment xli. And since upon the whole by opposing either fine points, blunted points, or surfaces of non-electric bodies at different distances towards electrified bodies, very different

ferent effects are produced, the air between the electric body and the body opposed seems to be one cause, which helps to resist the exit of the electric matter, and occasion these differences.

EXPERIMENT XLVII.

IF the needle or any other small quantity of non-electric matter pointed, have either of its ends *stuck* into wax, and afterwards brought in contact with the vial whilst it is electrifying, the filings in the vial (to all appearance) will be no more electrified than in experiment xxiv.

OBSERV. XIII. From this experiment it appears that the resistance is made very little less than in experiment xxiv, as there is not a quantity of non-electric matter to pass from the vial, and expand itself in.

EXPERIMENT XLVIII.

IF the same pointed body be stuck upon a very thin piece of wax, the opposite part of the wax to the fixed point, being in contact with the earth, and the other point at the same time brought in contact with the vial, the filings in the vial will be more strongly electrified than in experiment xlvii.

OBSERV. XIV. For the resistance to the passage of the electric matter from the vial into

the earth is made less by the interposition of thin wax.

EXPERIMENT XLIX.

IF instead of a thick quantity of wax, which we before supposed the person to stand on, we make use of a quantity that is very thin, as in the last experiment, the effects in all respects will be very different from what are mentioned in those experiments where the thick wax is made use of: for the person will not be so strongly electrified, the other circumstances being the same; though a greater quantity of electric matter will pass from the vial. It will be longer also before the light at the wire w appears, as well as before light bodies are moved too and from the bar, at the greatest distance. The accumulation of the electric matter in the filings in those circumstances will also be greater at equal distances, but less than the accumulation in experiment xxv.

OBSERV. XV. From hence it appears, that the resistance is farther varied and made less by the thin wax: and yet the resistance is greater, than when no wax is interposed: therefore there must be still different degrees of accumulation of the electric matter.

EXPERIMENT L.

IF any of the non-electric bodies mentioned in the xlith xlii^d and xliii^d experiments, are placed in contact with the vial and the earth at the same time, a light body placed at a small distance from the bar, upon the earth, will not be moved towards the bar at the first, second, third, or fourth turn of the wheel. But when the light issues from the wire w, then (or a very small interval of time before) the light body will be readily moved to and from the bar very quick.

EXPERIMENT LI.

IF nothing touches, or is near the outside of the vial, the same light body placed at the same distance from the bar upon the earth will, on the first turn of the wheel, be moved to and from the bar very quick.

OBSERV. XVI. From these last experiments it appears, that the electric matter coming from the machine into the bar, does not pass so readily from the sides of the bar, as into the filings, until the electric matter is accumulated in the filings to its greatest degree.

EXPERIMENT LII.

IF the glass vial be very thick, then those experiments will not succeed; for a very little only of the electric matter will be found to pass

pass through the glass, therefore the effects are very different.

OBSERV. XVII. From this experiment it appears that the resistance may be made too great.

EXPERIMENT LIII.

IF the glass vial be exceedingly thin, those experiments will not succeed in the manner we have mentioned neither; for the electric matter will be found to pass more readily thro' the thin glass than thro' a thicker glass, as we have shewn by experiment iii. sect. ii. and observ. xiii. and xiv.

OBSERV. XVIII. From this experiment it appears, that the resistance may be made too little.

THE same thing is manifest from points, and the surface of the bar in observation i. where it appears that the electric matter passes away the quickest, where the resistance given to its exit is least.

COROLLARY.

FROM the whole it follows, that in order to produce the greatest accumulation of electric matter, it is necessary there should be a certain degree of resistance; and that the resistance should be equal and uniform. For it has been found, that if the glass be of an unequal thickness, or have a flaw, hole, or crack in it,
the

the electric matter will escape more readily through those parts, than through any other part of the glass.

THAT this uniform and equal resistance alone is necessary for producing the greatest accumulation will be farther confirmed from the two following experiments.

EXPERIMENT LIV.

IF the vial be covered on the outside with a non-electric, if points and edges are avoided, on electrifying the outside thereof only, the same effects to all appearance will insue. This will be determined by a very easy method in proposition xi.

EXPERIMENT LV.

^a IF a plane of glass G (fig. 6.) of the same thickness with the vial, be covered close on each side with a non-electric, suppose leaf gold, silver, brass, or thin lead t, leaving an inch and an half or two inches uncovered all round the glass on each side next its edges e e e, on electrifying either side, suppose t, whilst the contrary side is in contact with the earth by means of the non-electric n, the electric matter will be accumulated to as great a degree on the electrified side t, as it was in experiment xxv.

^a This experiment was made by Mr. Smeaton.

UPON the whole, from the preceding experiments, we gather the following general truths, with regard to different bodies resisting the passage of the electric matter with different degrees of strength.

1. THAT glass, wax, and other electric bodies resist or obstruct the passage of the electric matter more than air : provided that the electric bodies are not very *thin*.

2. THAT one inch of air seems to resist less than one foot of air ; and one foot less than three feet ; and so on.

3. THAT air in general resists more than the surfaces of non-electric bodies.

4. THAT the surfaces of non-electric bodies resist the passage of the electric matter more than the obtuse ends, blunt edges, or obtuse angular terminations of the same kind of bodies.

5. THAT obtuse ends and blunted edges or obtuse angular terminations of the same kind of bodies, resist the passage of the electric matter more than fine points, sharp edges, or acute angular terminations of the same kind of bodies.

6. THAT the finest points, edges, and angular terminations of non-electric bodies, resist the passage of the electric matter *least* of all.

WHEN

WHEN we hereafter speak of the resistance, or obstruction of glass, wax, air, non-electric surfaces, obtuse non-electrics, or acute or fine points, or edges of non-electric bodies, we would be understood to mean that power or resistance, whatever may be its cause, which prevents the passage of the electric matter more, or less, as the bodies made use of differ in shape and kind.

It may seem difficult to conceive, how different degrees of accumulated electric matter in the same body are caused, by varying the resistance the fluid meets with in its tendency to dissipate, as was shewn in the proof to the last proposition, since it appears that the least accumulation is caused when the resistance it meets with is increased, and the greatest accumulation when the resistance is decreased.

Now some perhaps may think that these surprising effects are owing to an attractive power of the earth, acting variously in different circumstances, and that the accumulation is proportional to the attractive power.

BUT were this supposition true, pointed bodies opposed to the vial at some distance, in the manner we have treated of, ought to produce the least accumulation of electric matter in the vial when compared with surfaces opposed at the same distance and in the same cir-

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cumstances ; whereas by experiment it is found they produce the greatest : and when any pointed body is in contact with the vial, the effects are the same with respect to the accumulation as when a surface is in contact with the vial, and in the same circumstances : therefore those effects must arise not from an attractive power, but from the resistance the fluid meets with in tending to dissipate and expand itself.

WE have shewn how to accumulate electric matter in the vial ; we will now shew how the original quantity of electric matter in the same vial may be lessened or attenuated.

EXPERIMENT.

SET the machine on wax, and let a person standing on the earth take hold of the outside of the vial, and instead of hanging it upon the bar BB, by the wire w, let that wire touch any part of the frame of the machine, or the person turning the wheel, who also must be on wax. Let a wire, or any non-electric body communicate with the bar BB and the earth, after forty or fifty turns of the wheel, take the vial away, but, whilst it continues turning, and afterwards, set it upon wax. And the original quantity of electric matter in the filings within the vial, will appear to be attenuated to such a degree, as to produce effects equally strong

strong with those mentioned in experiment xxv. where the electric matter was accumulated.

ALL the effects we yet know of, arising from this attenuation, are the same with those produceable from the accumulation; excepting that remarkable difference of the acceding and receding of light bodies particularly related in the experiments following proposition iv. which hold equally true in this case.

PROPOSITION VIII.

The electric matter, when accumulated, seems to be dissipated, on causing an explosion, not only through the part where the explosion is made, but through the whole surface of the body, even though an electric body be interposed, provided it be thin.

EXPERIMENT I.

^a Let a thin plate of glass ten, fifteen, or twenty inches square be gilt with leaf gold on each side (or covered with sheet lead) within two inches of the border; or rather,^a let the thin glass vial V (that being most commonly used) which is filled with filings of iron, be covered close on the outside with sheet lead, leaving about two inches and a half uncovered at

^a This experiment was made by Mr. Canton Master of an Academy in Spittle Square, London.

the neck. Electrify the matter within, by means of the wire *w* passing through the neck of the vial, whilst the outside covering is held by a person standing on the earth. When it is electrified, set the vial upon any electric body *R* ; this done, approach the wire *w* with your finger, and there will be an explosion ; upon repeating it, a second, and a third will ensue, and so on. The like will happen on approaching the external leaden covering ; when you have touched that so often till the explosions cease, approach the wire *w* again and an explosion will again ensue ; after this, you will have another from the outward covering ; and so alternately from each, until the whole accumulated matter is nearly dissipated.

EXPERIMENT II.

IF the non-electric covering on the outside of the vial be but half an inch, or an inch in extent, these effects will be less from the covering than in the other case where the covering is larger.

EXPERIMENT III.

IF the glass be very thick, these effects are not produced.

THESE phænomena seem to be owing to the force of the explosion ; for as the explosion seems to be made only when the electric matter is sufficiently condensed, or collected into a kind

kind of focus, and as action and re-action are equal, the particles next in succession to those in the focus may be supposed to be checked or repelled, and those to check or repel one another with equal force. By which means those particles lying nearest the surface of the glass within the vial, may be forced through the thin glass into the non-electric body on the outside. And consequently if a non-electric cover the greatest part of the surface of the glass, and the glass itself be of an *even thickness*, the particles must be forced *equally* into the non-electric from all parts alike. Now supposing this the case, the greater the explosion is, the greater must be the check, or repelling force; and consequently the more the electric matter forced through the glass into the surrounding covering.

AND again, the greater or less the non-electric covering on the glass is, the greater or less also must be the quantity of electric matter forced through the glass into the covering. All this we find to be true in fact.

COROLLARY I.

IF this reasoning be true with respect to the effects produced by the explosion where a thin electric is interposed, it should hold equally true where the electric body is not interposed, as in that case the resistance is less. And there-

fore we suppose that when the bar is electrified, and an explosion caused, all the electric matter that does pass off from the bar at that instant, does not pass out at the point, or part where the explosion is made, though the most considerable part may escape there, but from every part of the surface; provided the resistance in all the parts of the surface be equal.

THIS equality of resistance may be had the nearest by making use of any polished metal-line body which is spherical.

THE accumulation of electric matter in the vial, bar, or sphere, is not totally dissipated by repeated explosions, as appears from the following experiment.

EXPERIMENT.

FIX a fine downy feather upon the wire of the vial, bar, or sphere; when they are electrified, approach them with a non-electric till the explosion cease: after which approach the feather and some of the fibres will move towards the non-electric and continue to do so upon the repeated approaches for several times.

WHEN one part of a non-electric body, or bodies but in contact with one another, suppose D, touches one side of an electric V, which has opposite on its other side a non-electric C in contact with it, and another part of the same body D is brought near the last mentioned

non-

non-electric C : the body D so disposed, together with the electric V, and the opposite non-electric C, we call the ^a *circuit*, and in such circumstances we say the circuit is completed. And the non-electric D completing the same, we call the *dissipator*.

THE electric V is represented by the vial V, (fig. 7.) The dissipator D, by the crooked bar of iron, wire, or chain, D. And the non-electric C, by the filings within the vial V and its wire w.

PROPOSITION IX.

WHEN electric matter is accumulated in the filings to the greatest degree, the loudness of the explosion and quantity of electric matter dissipated on completing the circuit, seem in some measure proportional to the points of non-electric contact with the *out* and *in* side of the vial.

PROOF BY EXPERIMENTS.

EXPERIMENT I.

WHEN the filings in the vial are electrified to the greatest degree, let the dissipator have that end very small which is to be in contact with the vial; on completing the circuit, there will be an explosion, but not a large one. If

^a This term was made use of the first by Mr. *Watson*.

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the circuit be completed a second or a third time, the second explosion to appearance will be the same with the first, and the third will be rather weaker, and so on, till nearly the whole accumulated electric matter is dissipated.

EXPERIMENT II.

IF the dissipator have that end much broader which is to be in contact with the vial (suppose two or three inches) the first explosion will be larger, and the second and third much less.

EXPERIMENT III.

IF the dissipator have that end next the vial so broad as to be in contact with the vial in every part for the compass of six or seven inches square, the first explosion will be much greater than the first, and the second much less than the second in the last experiment.

EXPERIMENT IV.

INSTEAD of filling the vial with filings, let there be only a very small quantity thereof in the vial, or let the inside non-electric contact with the vial be no greater than in the first experiment, and afterwards that non-electric electrified; on completing the circuit with the same point of the dissipator opposed to it, there will be no visible explosion.

EXPERIMENT V.

INCREASE the contact in the vial, so that it may equal the contact on the outside thereof mentioned

tioned in the second experiment: on electrifying the inside and completing the circuit with the same point of the dissipator on the outside, an explosion will be produced, but less than that in the first experiment.

EXPERIMENT VI.

IF the contact on the outside be increased so that it may equal the contact in the inside mentioned in the first, second, and third experiments; and the inside contact be no greater than the outside in the first experiment; the effects will be the same with those mentioned in that experiment.

EXPERIMENT VII.

IF the inside and outside contact are alike, and equal to the outside contact in the second experiment; the effects will be less than those mentioned in the second experiment, but greater than in the first experiment.

IF the inside contact be equal to the outside contact in the second experiment, and the outside the same with the second experiment; the effect will be the same with those mentioned in that experiment.

FROM these experiments it appears, that the greater the surface of a non-electric body is which touches the outside of the vial when filled with filings, the greater the explosion and dissipation. And that the less the surface is, the

less are those effects: but the greater the surface of the non-electric, the greater the quantity of contact, and *vice versa*. Therefore the proposition is true.

THIS is farther confirmed by proposition viii. with its proof and experiment lv. proposition vii.

SECTION VI.

WE have shewn what effects arise from a non-electric body when it is in contact with the outside of the vial. We will now cover the outside of the vial with a non-electric properly, by which means it will be better fitted for more extraordinary experiments, and the vial, when covered, may be said to be properly prepared.

To do this, take the same vial made use of before, or let a quart or larger vial V of the thinnest kind, and as *equally* so as can be had (the longest kind are the properest) be almost filled with clean filings of iron, quicksilver, granulated lead, or water: if it be with filings of iron, take care that they are shaken together very well, so that they may lie close to the sides of the glass: then put a cork into the neck
of

of it, and force the wire *w* through the cork into the filings. The wire *w* should be very thick, and the outer end rounded off. After this, wax all the cork which is without the vial. Now take a clean thin piece of milled, or sheet lead (such as comes from *India* in which tea is brought) as much as will wrap twice round the vial, and cover the surface of the vial from the bottom to within two inches and an half of the cork. Roll this piece which we call the *covering*, very tight round the vial, and afterwards bind it very well with one continued piece of wire, well nealed; and where you discontinue the binding, make a loop *X* for a bar, chain, or wire *D*, to be hooked on, as occasion may require.

Now any part of this covering, or the loop *X*, may be touched with the dissipator (when the circuit is to be completed) for the effect will be the same^a.

N.B. IF the vial could be covered over with quicksilver in the manner looking-glasses are, or with any other non-electric body without points or edges, it would be preferable to the leaden covering and its binding wire.

^a This method of covering the vial with *lead* was discovered by Dr. *Bevis*, which is indeed preferable to mine with water, which I at first made use of, as it is more convenient to manage.

PROPOSITION X.

WHEN the electric matter is accumulated in the vial to the greatest degree, the greatest effects are produced by completing the circuit.

EXPERIMENT.

Let the filings in the coated vial be electrified to the greatest degree possible under such circumstances (see experiment xxv. section v.) then if a person with one hand touch the covering of the vial, and with the other approach the wire *w* at the same time, he will receive a much more painful shock, than if he approached the wire *w* only (here we suppose the vial to continue hanging upon the bar or set upon wax.) If horses, oxen, sheep, dogs, or any other animals be the dissipator or part of it, they appear to be affected in like manner. The explosion also will be much greater, and the accumulated matter will be in a manner totally dissipated.

THE explosion will be still something greater, and the accumulated electric matter will be also in a manner totally dissipated, if a single piece of iron be the dissipator instead of the person.

IT has been already shewn (by proposition viii.) that when the vial is electrified and placed upon an electric body, the approaching
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of the wire *w* only will not discharge the whole of the accumulated electric matter: nor indeed will it make any apparent difference, as some perhaps might imagine, if the covering be touched and the wire *w* approached at the same time, but with separate bars of iron equal in weight to the quantity of non-electric matter contained in the vial; nor even supposing the bars or other non-electric matter to be increased to any quantity whatsoever. But when the external covering is touched at the same instant of time that the wire *w* is approached, either by two different bodies of the same kind, but in contact with each other, or by one only, and that either large or small, which we have called the dissipator, the case is then widely different, for the electric matter is in a manner totally lost and dissipated.

How this is effected is not easy to say, nor shall we take upon us absolutely to determine, being as yet not thoroughly satisfied from experiments. However, in order to assist those who may pursue these inquiries farther, we shall set down several experiments of different kinds, and from them propose a query how the completing the circuit seems to cause so sudden and great an explosion and dissipation of the electric matter.

EXPERIMENT I.

WHEN the filings in the vial are electrified to the greatest degree (which in each of the following experiments we shall always suppose to be the case) set the vial upon a cake of wax, and let nothing touch either the vial or the wire w, and it will be a considerable time before the electric matter will be dissipated.

EXPERIMENT II.

LET the vial stand on the earth and there will be (to all appearance) but a very little difference; the electric matter taking up rather a less time before it is dissipated, than in the first experiment.

EXPERIMENT III.

SUPPOSE the vial for this one experiment to have any part of the bottom or sides ground *extremely thin*, and to be electrified to an equal degree with the foregoing experiments; in order to do this, let some sealing-wax be put upon the thin place whilst it is electrifying, and after the vial is electrified, take the sealing-wax away, and set the vial on the earth; so that a non-electric may touch the thinnest part of the glass and the earth at the same time. The accumulated electric matter in these circumstances, will be dissipated nearly in half the time it will in the first or second experiment.

EXPE-

EXPERIMENT IV.

WHEN the filings within the vial V are electrified and set on any electric R, if a person standing on the earth, touch with his hand, or hold the wire w that passes into the vial, for some time, he will cause the whole of the accumulated matter within the vial to be dissipated in a shorter time than in the first or second experiment.

EXPERIMENT V.

LET a fine feather, whose fibres are long and slender, be fixed upon the bar BB, and let the bar be electrified; when it is, cease to turn the wheel, and the fibres of the feather will move towards a non-electric when approached near it, though a person standing upon the earth continues to hold the bar in his hand for some time. This experiment is similar to the last experiment, and as such we have introduced it here.

EXPERIMENT VI.

AGAIN, instead of touching the wire w with his hand, as in the fourth experiment, let him hold the point of a needle in contact with the wire after the vial is electrified, and set upon wax, in this case the whole of the electric matter will be dissipated in a very short time compared with the first, second, third, or fourth experiment last mentioned.

EXPE-

EXPERIMENT VII.

IF the sixth experiment is repeated with the same circumstances, except that the person now stands upon an electric R, he will be electrified in a small degree, and the whole of the accumulated matter in the vial will not be dissipated in so short a time as in the sixth experiment.

EXPERIMENT VIII.

WHEN the vial is electrified, set it upon the earth, and let a person standing upon wax touch the wire w, the accumulated electric matter will not be dissipated as soon to appearance as is mentioned in the sixth experiment.

EXPERIMENT IX.

ELECTRIFY the vial again, and let the person standing on wax now take hold of the covering of the vial instead of the wire w, at the same time let the wire w touch the earth; and there will be a considerable difference; for the accumulated electric matter will now appear to be dissipated sooner than is mentioned either in the first, second, or eighth experiments, and very near in the same time with the fourth experiment.

EXPERIMENT X.

LET the covering of the vial V be brought within an inch and an half or thereabouts of the top of the neck, and let the outward extre-

mity of the wire w be covered with dry wax: soon after the vial is filled with electric matter, a light appears to issue from the wire at the neck, which light tends towards the covering, and in a little time explodes, provided the wheel be continued turning. After this a second effect equal to the first cannot be produced without electrifying again. Nor is there any sign of electric matter being left within the covering.

EXPERIMENT XI.

AGAIN let there be fastened to the covering of the vial V, a wire or chain C, one, two, three, or more feet long: and let the vial be electrified to its greatest degree, and then placed upon wax. If the wire or chain be taken hold of, even with an electric R, and brought by means thereof to the wire w, so as to complete the circuit, a large explosion will ensue, and almost the whole accumulated matter will be dissipated. If instead of holding the wire or chain in the manner abovementioned, either of them be dropped upon the wire w, the effects, to all appearance, will in every respect be the same. In both these cases, after the large explosion, a small one, or two, may be produced by repeating the circuit, after which no electric matter will be found in the wire or chain C upon a person's touching of them.

EXPE-

EXPERIMENT XII.

^a IF the dissipator D be a bar, wire, or chain, and there be a piece of gilt leather, about the size of a crown, with its edges waxed round, fixed in the middle, either to the approaching part of the dissipator, or the part of the wire w approached, on electrifying the filings in the vial, and completing the circuit in the middle (or thereabouts) of the leather, a visible hole will be made through the leather (a strong proof that the electric matter passes through bodies) and a loud explosion will ensue.

EXPERIMENT XIII.

IF the end of the dissipator D, next the covering of the vial, or the covering it self, have also a piece of gilt leather fixed to it at the same time that the other piece is on the other end of D, or the wire w, the filings being electrified, on completing the circuit in the middle or thereabouts, of each piece of leather, a hole will be made through each, and to all appearance in the same instant. In these experiments where the circuit is completed, the same effects to appearance are produced, whether the dissipator touches the wire w or the covering first.

THE following account is a description of

^a Dr. Bevis observed this effect; the experiment he made was much the same with this.

an apparatus like that of the vial with its circuit to condense air in. It is so contrived that the effects arising from condensed air may be compared with those arising from the accumulated or condensed electric matter in the electrified vial.

LET *V* (fig. 9.) represent a vessel of glass; *W* a hollow pipe exhausted of air fitted close to the neck of the vessel *V*, so that no air can escape: one end of which opens into the vessel, the other end has a stop-cock at *n*. Let *DD* represent another hollow pipe communicating with *V* at *z*; and with *W* at *y*, like the dissipator: at which places there are also stop-cocks. And let there be also another stop-cock at *x*.

CASE I.

SUPPOSE now these stop-cocks *x y* and *z* turned, or shut, so that no air can pass from *V* into the pipe *DD*, or through *x* into the air without. Condense four atmospheres of air into the vessel *V* through the stop-cock *n*: then turn the cock *n* till the aperture in it is almost closed, and only a very little air escapes through it. If the time from its first beginning to issue to the time it ceases to issue be now examined, it will be found to be very considerable. See the first experiment, proposition i.

CASE

CASE II.

SUPPOSE every thing as before, but instead of letting the condensed air escape through *n* into the open air without, let it escape through the same aperture into an exhausted receiver, which held, before it was exhausted, more air than is condensed in *V*. And it will take up a shorter time to escape or expand itself in to the same degree, than it did in the first case. See the fourth and fifth experiments, proposition *x*.

CASE III.

CONDENSE the same number of atmospheres into the vessel again, and turn the cock *n* as before, leaving, as near as can be judged, the same, or an equal passage for the condensed air to escape into the open air: immediately after this, suppose the stop-cock *x* to be turned, leaving also a passage for the air to escape through it as it did from *n*, but somewhat larger. The rushing out of the air then through each passage will not be equal, but rather greater from *x* than *n*: therefore the condensed atmospheres will escape, or pass out through these two passages or apertures in *x*, and *n*, nearly in half the time they did from a mean between the first and second cases. See the third experiment, proposition *x*.

CASE

CASE IV.

SUPPOSE now the passage for the air to escape, at *n* (the vessel being again equally filled with air) to be a little larger than the passage for the air to escape at *x*, the aperture at *x* continuing the same as in the last case, then the greatest quantity of air will escape from *n*: and the time it will take up before the condensed air has escaped through both, will be shorter than in the last case. See the sixth and ninth experiments, proposition x.

CASE V.

TURN the cock *x* so that no air can escape by it, and condense the air again to an equal degree as before, leaving the aperture *n* as small as is mentioned in the first case: immediately after this, suppose *y* and *z* to be turned at the same instant of time, that the air may escape into the pipe *DD*; in this case it is easy to conceive that there will rush out a greater quantity of air in a shorter time than in the fourth case. See the *x*th, *xi*th, *xii*th and *xiii*th experiments, proposition x.

It is manifest too, that as the air in the pipe grows denser and denser as more rushes into it at each end, the entrance of the air will be slower and slower; as it will be every instant more and more obstructed by reason of the density encreasing every instant, till it becomes

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of an equal density with that in the vessel, and then no more can enter the pipe.

Now if the air could be discharged the instant it attempts to enter the ends of the pipe, it would, by its extreme quick motion, cause a single report.

QUERY II. Do not the phænomena producible from the vial, when the matter within it is electrified, square with these experiments relating to air? For as we said before, they appear to be similar as to their elasticity, and so far they ought to be governed by the same laws: which indeed seems to be the case, as thus:

THE vial V filled with air, and the vial V filled with electric matter, are vessels of the same kind; the obstructions, or different resistances to its passing out of the vial, are the stop-cocks n, x, y, z: for example, n represents the obstruction arising from the wire w; x the obstruction of the glass; y and z are the obstructions at each end of the body D completing the circuit: and the hollow pipe DD is the dissipator D, which completes the circuit.

THE first case, where all the stop-cocks are shut, except that at n, is similar to the electrified vial placed as in the first experiment; for in that experiment the resistance at the wire w
may

may be considered as similar to the stop-cock at n.

THE second case, where the exhausted receiver is fixed to n, is somewhat analogous to the fourth and sixth experiments: for in these experiments the resistance was made less by the non-electric contact, and here it is greatly lessened by taking away the air.

THE third case, in which the stop-cocks n and x are near equally opened, is similar to the third experiment, where the resistance given to the passage of the electric matter is lessened by a non-electric touching the thinnest part of the glass.

THE fourth case, where the stop-cock n is more opened than x, is somewhat similar to the sixth and ninth experiments, in which the electric matter is found to dissipate faster where the resistance is least.

THE last case may serve to illustrate the xth, xith, xiith, and xiiith experiments. For by proposition viii. the electric matter, on causing an explosion, is found to pass both by the wire w and the covering. And by the xiith and xiiith experiments, it is found that the explosion, and quantity of electric matter dissipated by that explosion, is greater when the circuit is completed, than when it is not completed: And it is further found that after an explosion, when

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the circuit is completed, there is no sign of any electric matter within the dissipator.

QUERY III. Do not these things shew that the electric matter is dissipated the quickest by this method of completing the circuit? And may not the large explosion which attends this experiment, be the result of several small explosions succeeding one another so quick as to appear but one?

QUERY IV. Now as action and re-action are always equal, must not the original quantity of electric matter within the dissipator be acted upon immediately after the explosion, in like manner as is shewn in the eighth proposition, so as to produce the same effects as if the accumulated electric matter had actually passed through the dissipator?

hituhio FOR two contrary (violent and sudden) motions, together with the ~~restrictive~~ power of the particles themselves, may be sufficient to cause that strange and painful shock or convulsion of the nerves and muscles, which is generally felt by animals, when they are so placed as to make up part of the circuit.

ALL the circuit experiments, and the experiment following proposition viii. seem to shew that this convulsive shock is proportional to the magnitude of the explosion. For the greatest shock is always produced when the
explo-

explosion is greatest ; and the least shock when the explosion is least. By parity of reasoning it follows, that there should be no shock where there is no explosion at the times of completing the circuit : and that it is the case, will appear from the following experiment.

EXPERIMENT XIV.

WHEN the filings in the vial are electrified to their greatest degree, let a person standing on wax, take hold of the covering of the vial with one hand, whilst in the other he holds a non-electric body, finely pointed, suppose a needle, with the point towards, and within two and a half or three inches of the wire w. By this means there will no explosion, nor any convulsive shock felt by the person holding it, yet in a very short time the greatest part of the electric matter will appear to be dissipated and lost.

OF the same nature with this last is the following experiment.

EXPERIMENT XV.

WHEN the filings are electrified, set the vial on wax, and fix the middle of the wire, which in this experiment is to be the dissipator, in a stick of sealing-wax, lest any one should imagine the electric matter passes into the person by this wire : then bring the ends of the wire equally near the covering of the vial and the

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wire w at the same time, suppose within an inch and a half of each. And if the room be darkened, a stream of light will be seen at the ends of the wire as long as any considerable quantity of electric matter remains within the vial. After this the wire that completes the circuit will not give the least sign of any electric matter being accumulated within it.

LET it be observed, that we cannot conclude from the diverging of the electric matter, which body it issues from: because the electric matter, both in passing out of a body and passing into it, has the same appearance.

THIS is manifest not only from reason but experiment.

EXPERIMENT XVI.

FOR, if a person standing on the earth holds a pointed body near the bar, whilst the wheel is turning, a light will appear to issue and diverge from the point.

EXPERIMENT XVII.

LET the same person now stand on wax, and take hold of the bar, and hold the point from the bar, and the same appearance of light (such as the divergency) will be at the point.

IN the first case, the electric matter passed into the person at the point, and in the last case, the electric matter passed out of the person at the point.

To shew this otherwise, let the person standing on wax with his arms extended from one another, hold in each hand a needle, and let one of the needles be within a few inches of, and point towards the bar, whilst the other needle points from the bar. If the bar be electrified, a light will appear at the point of each needle, and seem to diverge from each point at the same time.

THE next experiment seems to illustrate all the reasoning we have advanced in the proof of this last proposition.

EXPERIMENT.

^a SET the vial, after the filings are electrified upon a cake of wax, and let a small ball of metal, paste, clay, or cork, not too heavy, be suspended at the end of a thread (moistened with water) hanging from the top of the room in such manner, as that the ball, when in a state of rest, may be within a few inches of the leaden covering of the vial. Upon a person's touching the wire *w* in the neck of the vial (he standing on the floor) a small explosion will ensue, and the ball will have moved from its perpendicular, or natural point of rest,

^a An experiment of the same kind with this was made by Dr. *Le Moignier* at *Paris*, and communicated along with some others to the Royal Society in *London*, by Mr. *Needham*.

towards the covering of the vial, where it will continue as long as the person continues to touch the wire (without being repelled) and whilst any considerable quantity of electric matter remains within the vial.

PROPOSITION XI.

IF a person completes the circuit by taking hold of the covering of the electrified vial with one hand, and by approaching the wire in the neck of it with the other, the greatest painful shock will be always felt in those parts which lie in the shortest line that can be drawn through the person making up the circuit from the outside covering to the wire. And this is universal, supposing the person an uniform non-electric.

IN the case abovementioned, the greatest shock will be given along the arms and across the breast; if a leg and an arm complete the circuit, whether they be on the same, or on different sides, the greatest shock will be given in those parts which lie in the shortest line of communication between the leg and the arm^a.

N.B. The filings must not be electrified to the greatest degree, lest the person who makes

^a This method of affecting any part of the body without affecting the other parts, I discovered in the year 1746.

the experiment, should receive any hurt from the violent effects of the electric matter.

THE safe method of trying this experiment, is to make use of the vial mentioned in those experiments following the ninth proposition. And instead of covering the outside of the vial with lead, and completing the circuit with a wire, let the person take hold of the uncovered vial, and grasp it close with one hand, whilst with the other he approaches the wire *w*; and the effect will be much less. And it will be still less if the person only touches the vial with his finger instead of grasping it with his hand by proposition ix.

PROPOSITION XII.

Non-electric bodies placed without the circuit, will, on completing the circuit, be affected in the same manner (but in a less degree) as if part of the accumulated electric matter had passed into them.

EXPERIMENT I.

ELECTRIFY the filings in the vial *V* (fig. 10.) and place the vial in a darkened room upon the wax *R*, on which lay likewise in any direction several pieces of iron *c*, *d*, *e*, *f*, *g*, in such a manner, that the first piece *c* may touch the outside covering of the vial *V*, and that the
rest

rest may not be distant from each other above $\frac{1}{4}$ of an inch. Approach the wire w which is in V with one end of the iron rod r, the other end resting upon c, and you will have an explosion, not only from the iron rod, but from the several pieces of iron c, d, e, f, g.

EXPERIMENT II.

THE same effect is observed when a piece of gilt leather S Y is made use of in the following manner. Let the end thereof S (fig. 11.) be in contact with the covering of the vial V, and when the filings are electrified, upon bringing the part t or x of the leather towards the wire w by means of an electric, an explosion will ensue, and at the same time nearly a light or small explosion will be perceived in the little intervals of the broken leaf-silver which lie between t Y, or x Y, without the circuit, as well as in the intervals which lie between S t or S x within the circuit. And those little explosions will be more in number, and also more visible, if a person takes hold of the leather at Y or x, and still more so, the nearer the person's hand is to t or x.

SECTION

S E C T I O N VII.

PROPOSITION XIII.

AN explosion never happens but when the issuing electric matter is very much condensed.

THIS appears from pointed metal bodies when electrified in dark places. For the electric matter, in passing from a pointed piece of metal, will be seen to issue from it in diverging rays; on bringing a non-electric body near it, that divergency lessens; and in proportion as the body comes nearer, the divergency grows less and less; till at length the rays continuing to close, and to recede more and more from their divergency, till they are brought to a kind of focus, an explosion is made.

FROM the electric matter first approaching towards a parallelism, and afterwards converging to a kind of focus before the explosion is made, the condensation must be greatest at the time of the explosion.

IF the acute end of this piece of metal be an exceeding fine point, no sensible explosion will insue, even though it be approached exceeding near by the non-electric: because the electric
mat-

matter will now appear to pass out nearly in a parallel direction, and more equally and fast, forming a kind of column or cylinder, whose diameter is exceedingly small and scarce perceivable. Therefore in such circumstances there cannot be any sensible explosion, as there is no sensible convergency.

PROPOSITION XIV.

THE greatest explosion, in certain circumstances, is from polished surfaces of metal; and this explosion is greater the larger the surfaces are, to a limited degree.

LET the point of a needle not electrified, be brought near another of the same kind which is electrified, and no explosion will be perceived, even though the room be darkened. If instead of these very fine points you take other non-electric bodies which have points not so very fine, there will insue a very small explosion; and if the non-electric bodies have obtuse terminations, the explosion will be more apparent. But the greatest explosion is from large polished surfaces of metal brought towards each other in like manner, provided the corners or edges of these polished surfaces are rounded off, or covered with wax.

THIS holds only to a limited degree; for on making use of very large surfaces, we have not

found the explosion to be increased in proportion.

PROPOSITION XV.

As it has been proved by experiments vii. and viii. sect. iii. that the electric effects are always proportional to the density of the accumulated electric matter, and as those effects are greatest in the densest bodies in their natural state, those bodies must be capable of receiving a greater quantity of electric matter, or in other words, of having the electric matter accumulated to a greater degree, than bodies which are rarer.

For when the vial V is filled with ashes, saw-dust, or cork, and electrified, the accumulation of electric matter will be less, than when the vial is filled with Venice turpentine, and less when filled with Venice turpentine, than with filings of iron, granulated lead, or quicksilver: supposing the electrifying power of the apparatus the same in each experiment, and the wheel turned an equal number of times. For the explosion is greater from the filings, granulated lead, or quicksilver, less from the Venice turpentine, and least of all from the ashes, cork, or saw-dust. So also the painful shock on a person's completing the circuit, is greater from the filings, granulated lead, or quick-

quicksilver, less from the Venice turpentine, and least from the cork-ashes or saw-dust.

AGAIN, if different spheres of metal, ivory, wood, and cork, but of equal diameters, be suspended on the bar and electrified, the largest explosions will be from the metal spheres, and the least from the wood and cork.



PART II.

SECTION VIII.

IN this part we shall first give a short account of the *æther* Sir *Isaac Newton* has treated of, and endeavour to shew, that the subtile fluid which he calls *æther*, and that which we have been speaking of, are one and the same. Then prove, that *light* is lodged in all bodies: and that, the denser bodies are, the greater is the quantity of *light* contained in them. Lastly, by the properties arising from the mutual action between *æther*, *light*, and *bodies*, we shall endeavour to solve some of the most remarkable effects of electricity: and attempt to confirm Sir *Isaac's* doctrine of *gravitation*, *cohesion*, &c.

SIR *Isaac Newton* supposes that there is an exceedingly subtile and elastic fluid, which readily pervades all bodies, and is by its elastic force expanded throughout the universe: that its elastic force in proportion to its density is immensely greater, than the elastic force of the air compared with its density: that the in-

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crement of the density of this fluid, in receding from a body, is as the quantity of matter in the body directly, and as the square of the distance from the center of gravity inversely.

To illustrate this increment of density, suppose the whole force of any globe to be contracted into a point A fig. 12. and a, b, two particles of *æther* placed at an exceeding small distance from each other. Suppose c, d, two particles also of *æther*, placed at an equal distance from each other. Then the diminution of density is such, that if a particle of matter B was placed between a, b, and another equal particle of matter C, between c, d; no regard being had to the quantity of matter in the particles B and C, the excess of force wherewith b presses the particle B more, than it is pressed by a, is to the excess of force wherewith d presses the particle C more than it is pressed by c, as the square of the distance A C, is to the square of the distance A B.

THIS fluid, which he calls *æther*, he supposes it to be densest in empty spaces, and rarest in the densest bodies. And in bodies of different densities, he supposes it to be rarer in denser bodies; and denser in rarer bodies.

HE likewise supposes that *light* enters the composition of all bodies, and that by the mutual action of the *æther* without the bodies upon the *æther* and light within bodies, a very dense graduated medium of *æther* is caused, which furrounds their surfaces to very small distances; and may be of different density, according to the quantity of light in each body. This graduated medium of *æther*, he seems to think, is the cause of the reflection, refraction, and inflection of light (see *Opt.* page 241.) also of cohesion, fermentation, &c. For a more particular account of this, and how gravitation is caused, we refer to a *Dissertation on the æther*, by Dr. Bry. Robinson.

THE electric matter has been proved in the first part of this treatise to be exceedingly subtle and elastic, and to be contained in all bodies we are acquainted with. And there is reason to think that it is densest in spaces void of grosser matter, as we shall endeavour to shew more fully hereafter from experiment and reason. Since therefore in these properties it strongly resembles the *æther*, we may look upon it as the *æther* joined with grosser particles of matter propelled from bodies by the force and vigour of its action.

COROLLARY I.

FROM the *æther's* being densest in the rarest bodies, and rarest in the densest bodies, it follows, that, if a body be made rarer by any means whatsoever, the *æther* in that body must grow denser. Because the parts of the body are removed to a greater distance from one another. And consequently the pores or vacuities in that body will be larger.

COROLLARY II.

AND if a body be made denser by any means whatsoever, the *æther* in that body will grow rarer, because the parts are brought nearer together : consequently the pores or vacuities in that body will be smaller.

COROLLARY III.

FRICTION will cause bodies to rarefy as well as the heat of the sun, or any other heat ; and those rarefied bodies will contract and grow denser on discontinuing the friction, or on removing their rarefied parts from the friction.

COROLLARY IV.

HENCE it is evident, that as bodies grow rarer by heat, *æther* flows into them from other bodies ; and that as they grow denser by cold, *æther* flows out of them into other bodies. So that the density of the *æther* in any particular body, is as the mean density of all other bodies in proportion to the density of
that

that body. And therefore the density of the *æther* in any particular body will be increased, when any other body or bodies are condensed, or when that body is rarefied. And on the contrary, the density of the *æther* in any particular body will be lessened when any other body or bodies are rarefied, or when that body is condensed ^a.

PROPOSITION XVI.

WHEN two bodies are rubbed against each other, the *æther* will flow in greater quantity into the rarefied parts of the bodies, than into those parts of the same bodies which are not rarefied: and that in a different degree as the parts of the bodies are more or less rarefied. And upon the parts of the bodies growing denser, the *æther* must pass out of the bodies where it meets with the least resistance.

WE have shewn from several experiments which follow the viith proposition, that different bodies obstruct the passage of the electric matter with different degrees of strength.

IF now it be true, what Sir *Isaac Newton* seems to think (and what we hope we shall be able to confirm hereafter from experiments) that there actually surrounds all bodies, to very small distances, a very dense graduated atmo-

^a See Dr. *Robinson's* Answer to a pamphlet intituled, *Remarks on Dr. Robinson's System of Muscular Motion.*

sphere of *æther* of different degrees of density, arising from the different densities of the bodies, and the different quantities of light contained in them, it will be easy to conceive how the *æther* may be retained within a body by the surrounding dense atmosphere of the *æther* obstructing or resisting in some measure its *exit* out of the body: and how some bodies which have this atmosphere densest, retain the accumulated *æther* longer than others which have it less dense. Such bodies are glass, amber, wax, resin, glue, and other electrics: for they, when electrified, will continue to act upon light bodies much longer than iron, and other non-electrics, when electrified. And for the same reason, glass, amber, wax, and other electrics, must be less capable of receiving the *æther* by communication, than metals and other non-electrics.

FROM the same principle we may conceive how the *æther* gains admittance through the small surrounding dense atmosphere of *æther*, into the body where it is to be accumulated.

FOR when the parts on the surface of the body G are rarified, that part of the dense atmosphere of *æther* which we suppose extended over the rarefied parts, must be rarefied also: and since that is the case, the obstruction or resistance given to the entrance of the
æther

æther into G, must thereby be lessened. Consequently if there be a flux of *æther* from C towards that part of G thus rarefied, the passage or entrance into G will thus be more easy.

LET us now inquire how a flux or flowing of the *æther* from the parts adjacent can be caused. And again, how it escapes into other bodies, and why friction only can produce these effects.

SUPPOSE the cushion C, which is to rub the cylinder G, to be one uniform dense body, of a given magnitude. And suppose the *æther* in that body, before any part of the body is heated more than another, to be of an uniform density. Let the cushion C be placed, along with the cylinder G, on a body which has the densest atmosphere of *æther* surrounding it: for example, wax or glass, R, as in the experiment following the ivth proposition. This being done, rarefy part of the surface C by rubbing it against G, and G will be rarefied also. The parts of both bodies being thus rarefied, the *æther* must grow denser in those rarefied parts than it was before by coroll. i. but the whole quantity of matter in the glass G is less than the whole quantity of matter in C, therefore (supposing no *æther* to flow from any body or place that lies without those bodies G and C) the *æther* in those parts of the bodies

H 3

which

which are not rarefied, must flow into their rarefied parts, by coroll. iv. And if a quantity of *æther* proportional to the rarefaction of the bodies, passes into the rarefied parts, it is evident that a greater quantity of *æther* must flow from C than G, before the *æther* within them, or in the parts which are not rarefied, is attenuated or rarefied to an equal degree in each.

Now, though the *æther* be denser in the rarefied parts of the bodies C and G, than it was before the friction, yet as the resistance given to the exit of the *æther* at those rarefied parts by the graduated atmosphere, is lessened, on account of the friction, the *æther* contained not only in those rarefied parts, but in the other parts of the body, may, by the apposition of a non-electric, pass off more readily than it otherwise would have done, and the quantity of *æther* in the whole body may thereby be lessened.

In this case we suppose the flux of the *æther* from the circumambient bodies is in a great measure prevented, and therefore as the expansive force continually decreases, the issuing of the *æther* must also gradually lessen, and in a short time totally cease.

THIS quantity cannot be lessened beyond a certain degree, because a certain quantity is re-

quisite to overcome, by its expansive force, the resistance given to its *exit*.

THIS is confirmed by experiment : for when the machine is set upon wax, we are not able to produce any more electric matter than a very small quantity, though the friction be continued for any length of time. See experiment following proposition iv.

ON adding more matter to C, the quantity of *æther* is increased, and consequently a greater quantity must pass off, than in the last experiment, before it arrives at the same degree of attenuation or rarefaction. This is also confirmed by experiment. See proposition iv.

HENCE we may see the reason why, when so large a mass of matter as the whole earth is added, it is not in our power to attenuate or rarefy the *æther* in it to any sensible degree : And why the electric effects in this last case are so much greater than in the preceding ones.

FOR the magnitude of the earth being immensely greater than the magnitude of the bar, the *æther* must flow in as great a quantity from the earth into C and G, as it passes from them into the bar, even though the friction be continued ever so long.

THE first experiment in section ii. confirms this, as well as the experiment following the

ivth proposition: for when any non-electric communicates with C and the earth; or the wax R is taken away, there will be a continual issuing of the electric matter from the bar, and that for any length of time.

THE flowing of the *æther* must continue so long as the friction, because the rarefied surface of the glass G removing every instant from the cushion, begins to cool and contract; so that the *æther* which flowed from C into the rarefied parts of the glass G must now pass away where the resistance to its *exit* is the least: which will be found to be in the wires ww. For the opposite or inner side of the glass G, together with the air contained in the cylinder, resist the *exit* of the *æther* more than the wires ww, in contact with the outer side, as it will be proved by experiments hereafter. And it cannot pass back again towards C, because the parts of the glass G at or near C, are more rarefied, than those parts of G that are farther removed from C. Neither can the *æther* pass into the air so copiously, as into the wires, it appearing from all the preceding experiments that air resists its exit more than grosser bodies.

FRICTION only then can cause these effects, as it gives the *æther* in the rarefied parts of the glass an opportunity to escape every instant into
other

other adjacent bodies where the resistance to its exit is the least. For the parts of the glass that are most rarefied, are moved from the friction of the rubber every instant. And therefore such bodies that resist the passage of the *æther* least, and happen to be nearest G as it turns round, must receive most of the *æther* that issues from G.

COROLLARY I.

HENCE we may see the reason why upon turning the rarified parts of the glass from the wires *ww*, as in the experiment following proposition i, the electric effects in the bar are considerably less. For in that experiment part of the electric matter passes into the frame of the machine.

COROLLARY II.

AND hence we may perceive the reason why equal effects can never be produced in the bar *BB* from the cushion and the glass, without friction; even though they are heated to any degree whatsoever, by the fire or the sun. See experiment i. section ii.

COROLLARY III.

HENCE also we may understand how it is that the flowing of the *æther* gradually lessens, and at last ceases on discontinuing the friction. And how the electric effects from the glass
grow

grow weaker as it cools and recovers its original state.

COROLLARY IV.

HENCE likewise we see the reason why two thick electrics rubbed against each other can never produce so strong effects as an electric and a non-electric body. And therefore why setting the machine on non-electric bodies, moistening the leather of the cushion (which when dry is in some degree an electric) and all other circumstances to keep an open communication with the cushion C, are absolutely necessary for producing the greatest flux of the *æther*. This agrees also with the first corollary to proposition iv. And again, why silk or hair lines, glass, amber, wax, resin, pitch, glue, and all other electric bodies which obstruct or resist the exit or entrance of the *æther* more than metals or other non-electric bodies, are the only bodies absolutely necessary to hang or set non-electric bodies upon, in order to see how far the *æther* is capable of being accumulated in any non-electric body in such particular circumstances. And why those last mentioned bodies should be always dry and free from dust and dirt. All which things are agreeable to what we have advanced in the first section.

PRO-

PROPOSITION XVII.

WHEN the *æther* is put into such a motion within a body as in the last proposition, it will throw off, by the violence of its action, sulphur, and other matter lodged on the surface or within the pores, where it is less intimately combined with, and united to the parts of that body.

FOR the electric matter, in passing out of bodies, is generally observed to be of a sulphurous nature from its smell. And if a hand, or any other part of the body be held for some time in the stream of the electric matter as it issues, the hand, or that part which is opposed, will acquire the same kind of smell: nor will it presently lose that smell. The same effluvia will likewise whiten red roses, as sulphurous steams are known to do ^a.

COROLLARY I.

HENCE the rose and hand seem to be a kind of strainers by which the more gross sulphurous and other particles are separated from the more fine and subtile ones of *æther*.

COROLLARY II.

FROM this sulphurous matter condensed in the focus along with the *æther*, and fermenting

^a The whitening of red roses, by placing them in the stream of the electric matter, was observed by Dr. Bevis.

with the nitrous acid floating in the air, it is probably that the sudden blast or violent explosion in electrical experiments is produced ^a: in like manner as Sir *Is. Newton* has observed that lightning, thunder, and fiery meteors are caused by sulphurous steams fermenting with that acid; for, says he, the air abounds with acid vapours; as appears by the rusting of iron and copper in it, the kindling of the fire by blowing, and the beating of the heart by means of respiration.

^a That air is necessary for the production of these effects, appears from many experiments; for if two non-electric bodies be included in a glass receiver exhausted of air, or to as great a degree as we are yet able, and one of those bodies afterwards electrified, on their being moved near each other there will insue no explosion like that we perceive when the air is not exhausted; but there will appear a faint light between the bodies, and this is only visible when the experiment is made in a dark place. This faint light seems to require a certain quantity of air within the glass; for it is most visible when the air is not rarefied to so great a degree as we are able.

That an acid in the air is requisite to produce the greatest explosion, appears from the experiments made when the wind blows northerly or easterly. For the effects are then greatest with respect to the explosion. And it is generally admitted, that the air abounds more with acid when either of those winds blow than when any other wind blows.

Again, when the air abounds with sulphur, as in hot weather, and when there is thunder and lightning, the explosion in electrical experiments is least.

WE

WE will illustrate this matter farther by the following experiments.

A LIGHTED candle will go out, and glowing coals cease to shine in the air pump on drawing out the air: nay, red hot iron will cease to shine in a short time, upon exhausting the receiver of air. Again, a candle will go out, glowing coals and red hot iron cease to shine in a small quantity of air so closely confined as to have no communication with the rest of the atmosphere. If two parts of a compound spirit of nitre (which is a strong acid spirit) be poured on one part of oil of cloves, or carraway seeds, or of any ponderous oil of vegetable or animal substances, or oil of turpentine, thickened with a little balsam of sulphur, the liquors grow so very hot in the mixing as presently to send up a burning flame. If a drachm of the same compound spirit be poured upon half a drachm of oil of carraway seeds, even in *vacuo*, the mixture immediately makes a flash like gunpowder. And well rectified spirit of wine poured on the same compound spirit flashes. Common brimstone and nitre powdered, mixed together, and kindled, will continue to burn under water, or in *vacuo*, as well as in the open air.

SECTION IX.

WHEN we hereafter speak of electric matter, we would be understood to mean the *æther* put into such a motion within a body, as to carry along with it sulphur and other gross matter. But when we speak of the *æther*, we mean the same fluid, but not put into that degree of motion.

LIGHT is proved by Sir *Is. Newton* to consist of particles of various sizes: but the particles of *æther*, he says, are exceedingly smaller than those of light.

PROPOSITION XVIII.

ÆTHER is more subtile than light.

FOR if *æther* and light are put into such a motion, as to be propagated to immense distances in a short space of time, and the particles of one of them continue to move on with an equal, or rather with an accelerated motion through the most dense bodies interposed (see experiment x. section iii.) whilst the particles of the other are either absorbed, or stopt by such interposition, or reflected from their surfaces; it follows that those particles which pass through the interstices of bodies, are more subtile than those which do not pass.

But

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But *æther* has been proved to pass through dense bodies, which light will not pass through, therefore *æther* is more subtile than light^a.

THE velocity of light is exceeding great, and though the particles constituting the different rays are of various sizes, yet they all describe equal spaces in the same time. To account for the propagation of light from the sun to us, in so short a time as seven or eight minutes, various have been the hypotheses framed. All these Sir *Isaac Newton* has endeavoured to show, in question xxviii. to be very erroneous, and from the force of reason joined to observation and experiments, substituted the *æther* we have so often mentioned, and this at a time when electricity was but little known.

PROPOSITION XIX.

DENSE bodies contain more light in their compositions than rare bodies, unctuous and sulphurous ones excepted.

THIS appears from their emitting light more copiously when their parts are sufficiently agi-

^a It may be reasonably objected, that this proposition is by no means sufficiently proved, since light will pass through glass, amber, gums, &c. which the *æther* will not, or, however, from what has hitherto appeared. For an answer to this, we refer to the remainder of this treatise, and particularly proposition xxvii. and xxx. where we undertake to shew that all bodies may be electrified.

tated, whether that agitation be made by friction, percussion, or putrefaction, or any other cause. For instance, dense bodies which refract and reflect light most strongly when exposed in the summer sun, acquire a greater heat by the action of the refracted or reflected light; and if the heat be increased till it be about four times hotter than boiling water, then such dense bodies will emit light so copiously as to shine.

PROPOSITION XX.

SUCH bodies as are unctuous and sulphurous have more light in their composition than others of the like density.

The more copious the emission of light is from bodies, when their parts are agitated, the greater is the quantity contained in them.

Now sulphurous bodies, acted upon by the rays of light collected into a focus by a lens flame, burn more vehemently than others of the same density that have less sulphur in them, or, in other words, emit more light; and must therefore have more light in their compositions.

COROLLARY.

SINCE all bodies refract, reflect, and inflect light by one and the same power, and their power of refraction is nearly as their densities,
their

their power of reflection and inflection must be in the same proportion.

THE quantity of light too in their composition is for the most part as their densities. It seems to follow then, that the power in bodies to refract, reflect, and inflect the rays of light, is nearly proportional to the quantity of light contained in them.

PROPOSITION XXI.

THE inflective, refractive, or reflective power of a body extends itself but a very small distance from the body.

FOR the rays of light in passing by bodies are not affected so as to be turned out of their rectilinear course, till they are very near the edges. *Vide Newt. Opt. III. L.* The cause of this power or medium, which surrounds all bodies, remains to be enquired into.

1. THE law established between the *æther* and bodies, for making the *æther* the cause of most of the phænomena of nature, respects both the quantity of matter and the quantity of light contained in bodies.

2 THAT part of the law which respects only the quantity of matter, we have given before, which in other words amounts to this: The body and the *æther* lying next to it all round, repel one another with a force which

is measured by a rectangle under the quantity of matter in the body, and the density of the *æther* applied to the square of the distance of the surface from the center of gravity of the body. If the body be a globe of an uniform density throughout, in which case the center of the globe will be its center of gravity, the *æther* will press on the globe by endeavouring to expand itself, and by that pressure it will recede from the globe, and its density will continually increase, and the increment or increase of density at any distance, will be as the quantity of matter in the globe directly, and the square of that distance from the center of the globe inversely. If the globe be large, the sphere of *æther* surrounding it, whose density thus increases, will be large; and the sphere of *æther* will be small if the globe be small. The sphere of *æther* surrounding the sun, occasioned by the action of that great body, extends much beyond Saturn, nay, beyond the distance of the remotest of the comets aphelium. The sphere of *æther* surrounding the earth occasioned by the action of the earth on this medium extends itself beyond the moon. Hence any body placed within a sphere of *æther* belonging to the sun, earth, or any other great globe will move towards it, the *æther* being denser on the remoter side of each particle of the
body

body than on its nearer side, with respect to the globe: if the globe be small, the sphere of *æther* surrounding it will be small; and the increment of the density, which at the surface of a globe is as at its diameter and density taken together, may be so very small as not to be able to produce any sensible motion in a small particle placed within the sphere of that small globe. The increment of the density of the *æther* at the surface of a globe of a given density, being as the semi-diameter of the globe: and the semi-diameter of the earth being 3965 english miles, or 251222400 inches, the increment of the density at the surface of the earth, and at the surface of a small globe of the same density with the earth whose semi-diameter is 1 inch, will be 251222400 and 1 the spaces described in 1" by a corpuscle moved by these forces will be 193 inches and $\frac{1}{1730187}$ part of an inch. Hence the corpuscle moved by the force of the little globe will be above 15 days in describing 1 inch, and consequently the force of gravity in the small particles of matter is altogether insufficient for producing the violent motions those particles have in fermentation.

THAT part of the law which respects light reaches but to a very small distance from the surface of bodies, and such as is mentioned in

the last proposition. The light which enters the composition of all bodies by powerfully repelling the adjoining *æther*, and thereby increasing its density to a very small distance (suppose to the eight hundredth part of an inch) from the surface of bodies, constitutes this force. That light and *æther* act with immense force on one another, appears from the rays of light (which move above 158000 English miles in a second of time) being turned out of their rectilineal course by the *æther* at the surface of bodies: for it requires an immense force to turn a body moving with so great a velocity out of a rectilineal course. Light and *æther* repel one another very strongly, and hence it is that light adhering to the surface of bodies, repels the adjoining *æther* with great force, and thereby causes a great and quick increase of its density to a small distance from the surface, such as is represented by fig. 13. from the particle or body A to b; at the end of this distance from the surface, that is, at b, the *æther* is densest: and much denser than it would be from the quantity of matter in the body. The force of light terminating at this distance, the *æther* condensed by that force will afterwards relax and rarify to some certain distance, suppose at c, and beyond that distance it will go on to be condensed by the sole action of

of the quantity of matter in the body to d, and beyond. The condensation and rarification of the *æther* at the surfaces of bodies constitute two forces, an impulsive force, which is from b to the body A, and a repulsive force, which is from b to c: those forces act very powerfully on minute particles which come within the limits of their action. Hence these forces are strongest in bodies which contain most light in their composition with respect to their densities, that is, they are strongest in sulphurous and unctuous bodies.

The narrow limits of the two forces constituted by light prevent them from affecting bodies of any sensible magnitude, for bodies must be so small as to fall within these limits before they can be moved by these forces. A body less than the eight hundredth part of an inch in diameter, suppose a (fig. 14,) placed between the densest part of the *æther* b and the surface of the body x, will move towards the body x by receding from the denser part of the *æther* towards the rarer. The same small body a, placed beyond the densest part of the *æther* b of the body x, will move from the body x by receding from the denser part of the *æther* towards the rarer. So that when the densest part of the *æther* b, caused by the superficial light of a body, falls without a small particle

a, (fig. 14) that particle a will move towards the body x: and if x be equal to a, they will move equally fast towards each other: and they will move from each other if the densest part of the *æther* b, c, lie between the particles x and a, (fig. 15) or in other words if the particles are placed any where within the bounds of their repulsive forces.

The rays of light seem to be reflected regularly by virtue of this medium evenly diffused all over the surface of a polished body. “ Sir *Isaac Newton* says, “ were the rays of light
 “ reflected by impinging on the solid parts of
 “ bodies, their reflections from polished sur-
 “ faces could not be so regular as they are. For
 “ in polishing glass with sand, putty, or tri-
 “ poly, it is not to be imagined that those sub-
 “ stances can by grating and fretting the glass
 “ bring all its least particles to an accurate po-
 “ lish; so that all their surfaces shall be truly
 “ plain, or truly spherical, and look all the
 “ same way, so as together to compose one
 “ even surface: The smaller the particles of
 “ those substances, are, the smaller will be the
 “ scratches by which they continually fret and
 “ wear away the glass until it be polished, but
 “ be they ever so small they can wear away
 “ the glass no otherwise than by grating and
 “ scratching it, and breaking the protuber-
 “ ances,

“ ances, and therefore polish it no otherwise
“ than by bringing its roughness to a very fine
“ grain, so that the scratches and frettings of
“ the surface become too small to be visible.
“ And therefore if light were reflected by im-
“ pinging upon the solid parts of the glass, it
“ would be scattered as much by the most po-
“ lished glass as by the roughest.” For these
rays only which fall upon the tops and bottoms
of the protuberances and cavities would be re-
flected according to the general direction of the
whole surface of the body: those which fall
upon the oblique sides of those protuberances
would be reflected in a different angle.

THAT medium which we have shewn to
surround all bodies to very small distances, and
which is supposed by Sir *Isaac Newton* to be
the cause of the reflection, refraction, and in-
flexion of light, we shall call by the different
names of the reflective refractive, or inflective
medium, or in one word by *atmosphærule*, as
will best suit our present purpose.

SECTION X.

PROPOSITION XXII.

THE *atmosphæra* surrounding any body prevents the electric matter, when accumulated within that body, from issuing so fast as it otherwise would, if there was no *atmosphæra* surrounding it.

FOR the electric matter, its expansive force being equal at every point of the surface of a body electrified, ought to expand itself and be propagated equally from all parts of the body into the air; and that as fast as it enters into the body: so that there could be no accumulation of the electric matter, (See Sect. iii. Experim. 7.)

BUT it is found that a globe of metal will continue electrified for some time; and that if a pointed piece of metal be fixed to it, the globe will not continue so long electrified: and the electric matter will issue most from the point. Whence it appears that there is something acting at the surfaces of bodies which retards the exit of the electric matter: and that more or less according to the circumstances which attend

tend the experiment. What this cause is, we shall now inquire.

THE pressure of the air upon the surfaces of bodies cannot be the cause ; for the pressure of the air on any given part of the surface of a pointed body must be equal to the pressure on an equal given part of the surface of any other body which is not pointed : and the pressure being equal in both these cases, the electric matter ought to meet with an equal resistance from the air. Yet notwithstanding we find that the electric matter passes off sooner from pointed bodies than from bodies that are not pointed : and that the dissipation is performed in the shortest time when the points are the finest. Besides, this holds equally true *in vacuo* : and therefore those effects may arise from the *atmosphærule* being rarer at a point, than at the surface of a body.

IF this supposition be true, it follows, that the rarer the *atmosphærule* is, the less will be the resistance to the exit of the electric matter. Now the finer points are, the more copious is the issuing of the electric matter from them ; therefore the proposition is true.

PROPO-

PROPOSITION XXIII.

THE electric matter upon its issuing suddenly through a denser *atmosphæra* produces a greater effect than when it issues through a rarer.

TO any part of the wire *w* (fig. 16.) fix a very thin piece of hard wax, glue, *Muscovy* glass, or common glass *G* in the middle, or which will answer better, a piece of gilt leather three or four inches in diameter; then when the vial *V* is electrified, bring the dissipator *D* towards the middle of the affixed body *G*, and the explosion will be much louder than it would be from any part of the wire *w*, supposing the vial electrified to the same degree.

N. B. THE leather must be varnished on the gilt side, and the edges of it covered with sealing wax.

IN this experiment the action of the electric matter is so strong as to make a hole through the leather, and to force quite away the varnish and silver, so as to leave the leather for some little space round the hole quite uncovered. It is remarkable that the space stript of the varnish is greater than the space stript of the silver.

IF the wax, or very thin glass be made use of in the above experiment, the violence of the action of the electric matter will break it.

PROPOSITION XXIV.

IN two or more circuits made at the same time, with the same vial, but with different bodies, the electric effect, supposing the filings in the vial strongly electrified, will be in that circuit only where the electric matter will meet with the least resistance.

Proof by Experiments.

EXPERIMENT I.

TO the loop x (fig. 17.) on the covering of the vial V, fasten one end of a wire C of any length, ten, a hundred, or a thousand yards, for it appears to be the same thing in the event of this experiment, and when the vial is electrified as usual, let the person P, who makes the experiment take hold of the vial V or the wire C at x, in one hand, and with the other hand H, laying hold of the other end of the wire c, bring that end of c towards the wire w, which is in the neck of the vial. By this means there will be two circuits made, as may be easily seen by the figure, the one with the wire and vial VCHW: and the other by the Person and vial VPHW. In such circumstances,

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stances, the person will not feel the electric effect, or in other words, receive a convulsive shock, as the resistance arising from the *atmosphærulæ* is less on the surface of the wire C, than in the person. This is manifest from reason as well as experiment; for the parts of the wire C are supposed to be incontact from end to end, so that there can be only the resistance arising from two *atmosphærulæ* to be overcome, namely, that at each end. Whereas in the person there are different kinds of matter distinct from one another, namely, the fleshy, bony, and nervous parts, besides the blood and other fluids, which have their different *atmosphærulæ*. But as it may seem difficult to conceive how bodies included within, or surrounded by other bodies in like manner as the nervous, fleshy, and other parts of animal are, should have their different *atmosphærulæ* surrounding them, we shall set down an experiment that will serve to illustrate this matter.

EXPERIMENT II.

POUR an ounce or two of well dissolved Venice turpentine into a thin glass cup, and afterwards pour two or three drops of milk, which has had the cream taken off, into the turpentine, in one part, and two or three drops into another part of the same cup, so that there may be two separate quantities, or drops of milk in the

turpentine; then turn the cup different ways, till the drops are brought as near together as you are able; for they will not mix till a considerable time after; then shake the cup, or let one drop press upon the other: and you will perceive an actual distance, though very small, between them: and the drops will be convex and concave to one another, and have their edges turned up like lips. Shake them again, and you will still find them to keep the same distance from one another, and retain something of the same figures. If the turpentine be not shaken for about fifteen or twenty minutes, the two drops will come together so as to make but one.

QUERY. If the *atmosphærule* surrounding those drops of milk in the Venice turpentine be not the cause of this phænomenon, how comes it that the drops should keep at a distance from one another and retain those singular forms, even though they lye upon one another?

Now, according to this reasoning, when the resistance arising from the *atmosphærulæ* in the person is less than in the other circuit, the electric effect ought to be felt in the person.

AND that this is the case will appear from the following experiment.

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EXPERIMENT III.

LET one end of a clean unruſted chain (for example, ſuch a one as is commonly uſed for a jack) and of the ſame length with the wire c, laying looſe or unſtretched, be fixed to the vial at x, and the other end be brought round by the perſon to the wire w, as the wire c was before in the firſt experiment, propoſition xxiv. And the electric effect will not be in the chain but in the perſon, and to much the ſame degree as if no chain was made uſe of.

IN this laſt experiment, we conſider each link of the chain as having two ſeparate *atmoſphærulæ*; for if any thing ſhould paſs or be propagated through each link, it muſt paſs or be propagated through two *atmoſphærulæ* in each link: one as it enters, the other as it paſſes out; and upon ſuppoſition that the ſum of theſe *atmoſphærulæ*, and the reſiſtance ariſing from them added together, exceed the ſum of the *atmoſphærulæ*, and the reſiſtance ariſing from them in the perſon, the electric effect muſt be in the perſon, or where the reſiſtance is leaſt.

EXPERIMENT IV.

AGAIN, ſhorten the chain, and thereby leſſen the number of *atmoſphærulæ*, till ſuch time as the reſiſtance ariſing from the *atmoſphærulæ* in the perſon added together, exceed the reſiſtance

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ance arising from the *atmosphærulæ* of the chain added together, and the person in these circumstances will not be affected. Nor indeed will the person be affected when a chain of any length is made use of, provided it be stretched tight, so that the links may be nearer contact with each other.

COROLLARY.

THEREFORE different pressures of the links against one another, whether it be caused by the weight of the chain, or by pulling it, will produce very different effects.

EXPERIMENT V.

THOUGH the electric effect be perceived in the person when there are two circuits performed, and the chain of a considerable length, and unstretched: Yet if one circuit only be performed, and that with a chain unstretched, the electric effect will be in the chain: as appears by the great explosion, and the many small ones between the links from end to end, which may be seen when there is but little light in the room. These small explosions do not appear between the links in the other experiments.

EXPERIMENT VI.

AGAIN, if the unstretched chain and a wire of an equal length make up the circuit at the same time, in the manner we have described
above

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above, the great explosion will ensue, but none of the small ones will be seen between the links of the chain.

FROM this last experiment we conclude, that the effect was along the wire in which was the least resistance, or the fewest *atmosphærulæ*.

IF the resistance should be the same in all the circuits, whether there are two or more, it is easy to conceive, they will all be affected alike.

WE have an experiment of this kind^a. It is performed in the following manner.

EXPERIMENT VII.

LET the vial V (fig. 18.) be electrified, and placed upon a metal plate P, and let several persons, three, four, five, six, or more, each of them take hold of the plate with one hand, and of a bar of iron dd, with the other: then let them move either the end or the middle of the bar dd towards the wire w, which passes into the vial, and they will every one be affected alike with a painful convulsive shock. Let them change places, and let the vial be electrified again, and the effect will be the same.

^a This experiment was communicated to me by Mr. G. Graham.

SECTION XI.

PROPOSITION XXV.

AS all gross bodies have their *atmosphæ-
rulæ* surrounding them, so it is proba-
ble the particles of air, which are heterogenous
(or a collection of many kinds of bodies) have
atmosphærulæ similar to the same kind of bo-
dies, which are grosser and larger.

FOR all bodies, whether solid or fluid, have
their *atmosphærulæ* by the viith, viiith, and ixth
sections, which *atmosphærulæ* will be (except-
ing such bodies as abound with unctuous parti-
cles) nearly proportional to their densities, by
proposition xviii. section ix. So that if a solid
or fluid be divided or separated into any num-
ber of parts, each part having light in its com-
position, may, by the action of that light upon
the *æther* without, have an *atmosphærule* con-
stituted. All bodies likewise, whether solid or
fluid, may have their parts separated from one
another by the action of heat. When the parts
of gross bodies are separated by heat, fermenta-
tion, or otherwise, and placed without the
reach of each other's attraction, then the parti-
cles recede from one another, and may consti-
tute

tute air. When the particles of any body do not cohere strongly, and such is the case with fluids, a small heat is sufficient to separate their parts and turn them into vapours. Gross bodies are with the greatest difficulty brought together, and upon contact they cohere most strongly. The particles of permanent air arising from such gross bodies by fermentation recede from one another with the greatest force. And because the particles of permanent air are grosser and arise from denser substances than those of vapours, thence it is that true air is more ponderous than vapour, and that a moist atmosphere is lighter than a dry one, quantity for quantity. See *Newt. Opt.* p. 372.

PROPOSITION XXVI.

A SUFFICIENT number of such last-mentioned particles, when placed in such a medium as the *æther*, may constitute an electric fluid somewhat similar to the atmosphere of our earth.

SUPPOSE any number of gross particles of different specific densities, for example, five orders, or degrees: and the first order of the least density, the second more dense, the third denser, the fourth denser than the third; and the fifth densest. Now suppose those particles at a given distance from the earth to be thrown

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confusedly into such a medium as the *æther* acting by the same law that gravity acts: it is evident that the densest particles will fall and be nearest the earth; but those particles having *atmosphærulæ* much stronger than the force of gravity, will be kept from being in close contact with the surface of the earth. The fifth order then will be nearest the surface, and supposing those to cover a given area thereof, the fourth, as being next in density, will press forward, and rest upon the *atmosphærule* of the fifth: the third will press upon the fourth as the fourth did upon the fifth: the second, as being still lighter, will rest upon the third, and the first upon the second. All these will form parallel plains (if the particles in each order are of equal densities) of an uniform density according to the order in which it ranks: the grossest and densest particles, as observed above, being next the earth, whilst the lightest will be removed to the greatest distance from it. And as the size of the particles of each order must be supposed very minute, and consequently their *atmosphærulæ* nearer to an uniformity than if they were still larger, they will be very easily moved among themselves on the least impulse, and herein they come under the definition of fluids. Supposing then some particles of the first order to be intermixed with others

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of the fifth, according to the laws of hydrostatics they must ascend, as being specifically lighter than those of the fifth, fourth, third, or even of the second order, and acquire so much motion as the access or defect of gravity is able to produce. Again, these particles being very minute may be looked upon as equal in their densities and diameters. Now as the density of air is found to be nearly equal, if not accurately so, to the force compressing it, the elasticity thereof will be in the same proportion, the centrifugal forces of the adjoining particles are reciprocally proportional to the distance of their centers (an elastic fluid, the density of which is as the compression, being composed of such particles, by proposition xxiii. lib. ii. *Newt. Principia*) the particles of *æther* therefore, lying in and between the particles of air, will be subject to the like laws upon compression, and consequently a sufficient number of the above-mentioned particles placed in such a medium may constitute a fluid similar to the air in our atmosphere.

PROPOSITION XXVII.

IF into a vessel whose *atmosphæra* is very great (for example glass) be put any kind of matter, and that be afterwards electrified, the resistance the electric matter will meet with in
passing

passing out on compleating the circuit, seems to be as the thickness of the glass, the quantity of non-electric contact with the glass, and the sum of their several *atmosphærulæ*; to wit, of the dissipator, the vessel itself, and the matter contained within it.

By the seventh proposition the electric matter will pass through a glass that is thin, but not through one that is thick^a. If the glass be very thin, the air alone contained within the glass may be electrified, and a convulsive shock will insue upon a person's completing the circuit. But this effect from electrifying air will not happen if the glass be thick; nay, though it be only of such a thickness as that when filled with filings of iron, it would produce the electric shock. It is plain then, that the thickness of the glass is one circumstance always to be regarded. The quantity of non-electric contact, both on the inside and outside of the vial, is another circumstance to be regarded by proposition ix. That bodies are surrounded by an *atmosphærule* which obstructs the exit of the electric matter, with different degrees of strength, according to the different density of the *atmos-*

^a To make this experiment, nothing more is required than to take a very thin vial which is dry, and put a cork into the neck thereof, through which cork push the wire w into the vial, and electrify the air within it in like manner as if it was filled with filings, quicksilver, or water.

phærule, appears from proposition xxi. The *atmosphærule* of the dissipator may be increased so as to be more in number by proposition xxiii. and made denser or rarer at pleasure, by interposing such bodies as resist the exit or entrance of the electric matter more or less. But supposing the dissipator in these experiments to be one single piece of iron, there will then be only two *atmosphærule* to be overcome, together with those arising from the wire *w*, and the covering of the vial. Therefore the sum of those resisting powers arising from their *atmosphærule* are given. And in respect to the latter part of the proposition, since the refractive power of bodies is nearly proportional to their densities, and the refractive power of air in proportion to its density is near that of glass, notwithstanding its rarity: if you take away the air, the resistance which the electric matter will meet with in passing through the glass towards the dissipator will be lessened: because in this case it will only meet with the resistance arising from the internal and external *atmosphærule* of the glass. But on the other hand when air is included within the same vessel, since every particle of air has an *atmosphærule*, the resistance arising from the *atmosphærule* of air must be added to the resistance arising from the *atmosphærule* of the glass. And therefore the resistance

ance given to the passage of the electric matter will be greater or less, as a greater or less quantity of air is included in the vessel. This is confirmed by making the experiment.

LASTLY, the electric matter will pass thro' a thicker glass filled with filings of iron, so as to give the electric shock, when it will not pass through the same glass filled with air. Because the resistance arising from the *atmosphærulæ* of the filings is less than the resistance arising from the *atmosphærulæ* of the particles of the air, as the particles of the filings are larger than the particles of the air: and on that account there are fewer *atmosphærulæ* to resist its passage; therefore the proposition is true.

COROLLARY I.

HENCE if the vial be very thick there will be little or no accumulation, by proposition vii. and consequently no explosion or convulsive shock on a person's performing the circuit with his hands, prop. x. experim. 12.

COROLLARY II.

WHEN the filings of iron in the vial are electrified, upon compleating the circuit three or four times one after another successively, without electrifying afresh, there will be but one large explosion, and sometimes will follow two or three very small ones, after which the whole quantity of electric matter will appear

to be dissipated. If instead of iron filings the vial be filled with water, there will issue a greater number of explosions. But the first explosion from the water will be fainter than the first from the filings; and the second and third explosions louder than the second or third from the filings: or in other words, the explosions from the water approach nearer in uniformity to one another, both as to loudness and degree of light, than those from the filings. But when the included air only is electrified, the number of the explosions will be increased further, and their degrees of loudness and light will be still less than in the last case: so likewise they will be more alike to one another as to loudness and degree of light.

QUERY. Do not these phænomena seem to be owing to the different *atmosphærulæ* surrounding the particles of water and air, which by their pressing between occasion a greater resistance, and thereby prevent the immediate and total dissipation of the electric matter? For take away the air, and accumulate the electric matter in the vial by the wire w as before, upon compleating the circuit the whole accumulated quantity will appear to be dissipated and lost in one single explosion, which seems to be a strong argument for the truth of what we have advanced. And when a body loses
any

any part of its original quantity of electric matter, as in proposition v. may not the electric matter, by reason of the resistance arising from the *atmosphærulæ* of the particles of the air be one, if not the only, cause why the electric matter is not supplied afresh from the air so readily, though more of it be contained therein than in the body? And for the same reason must it not be retained in the body?

SECTION XII.

PROPOSITION XXVIII.

FROM the different density of the *atmosphærulæ* surrounding bodies, it is that some bodies are electric and others non-electric; regard being always had to the texture of the bodies. Such bodies as have the densest *atmosphærulæ* supposing them not fluid, moist, or soft, are called electrics; and those which have the rarest *atmosphærulæ*, non-electrics.

THE truth of this proposition seems evident from what has been said before; for it has been proved that the electric matter passes into or out of those bodies most readily, where the resistance given to its exit or entrance is the least; and the resistance given to the exit or entrance
of

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of the electric matter has been shewn to arise from the *atmosphærulæ* which surround bodies by section x. and to be in proportion to their different degrees of density. Those bodies therefore whose *atmosphærulæ* are the densest (and such are all electrics by proposition xvi.) have not the electric matter communicated to or accumulated in them to any great degree without friction : whereas those bodies whose *atmosphærulæ* are rare (and such are called non-electrics) will suffer the electric matter to pass readily into, and be accumulated in them, and that to a high degree by communication only ^a.

COROLLARY.

HENCE it appears that the resistance given to the electric matter does not absolutely arise from the nature and quality of the internal and constituent parts of bodies, but chiefly from the *atmosphærulæ* on their surfaces. This will appear yet more fully hereafter.

PROPOSITION XXIX.

ANY fluid included in a vessel may be electrified, though the *atmosphærulæ* of many fluids

^a It may be objected that this proposition is not sufficiently proved : for if the *atmosphærulæ* are proportional to the densities of bodies, gold, as it is the densest body, ought to be a strong electric, whereas experience manifests the contrary ? In answer to this, see proposition xxx.

are much denser than that of common glass, as may be gathered from their refractive powers being much greater than the refractive power of common glass. This is the case with oil of olive, linseed oil, and spirit of turpentine.

THAT all fluids are non-electrics is evident from their being readily electrified, as any one may be convinced by putting the fluid into a vessel, setting the same on wax, and letting a wire or any other non-electric touch the bar and the fluid in the vessel. For upon turning the wheel, the like phænomena may be produced from the fluid, as was done from the bar in the first experiment, section ii.

BUT that a fluid whose *atmosphærule* is so very dense should be capable of being electrified at all, may seem difficult to account for consistent with what is before advanced; to wit, that bodies are rendered electrics by the great density of their *atmosphærulæ*; together with a certain texture of the body. For some may ask, whence it is that linseed oil should be a non-electric, and glass an electric, when the *atmosphærule* of the former seems to be much denser than that of the latter? To which we answer, that from all the experiments we have yet made of bodies being electric, in proportion to the density of the *atmosphærulæ*, this law, which holds true in all solid bodies, does not obtain in fluids:

one reason of which at least may be as follows. That an alteration on the surface of fluid bodies may be caused by the action of the electric matter; so that the *atmosphæra* may be rendered rarer, or the resistance to the entrance or exit of the electric matter made less; when it may not be the case if the body be solid, it being the property of fluids that their parts should yield to any force impressed upon them, and by yielding, to be easily moved among themselves.

N. B. THE blast resembling wind seems to arise from the particles of air being put into a violent rapid motion by the issuing of the electric matter, which must necessarily be greatest at points, edges, or angular terminations, as the electric matter flows through them most readily. That the air is put into such a motion appears from the two following experiments.

EXPERIMENT I.

FIG. 19. represents a cork stuck upon a needle, with small bits of paper let into its sides, which serve for vanes; when the other end of the needle is suspended by the magnetic virtue of a load-stone or piece of steel, it may be easily turned round with a very small force. If the cork thus suspended be brought near the point of any body which is electrified, it will be

be turned round very quick, and continue to do so whilst the body continues to be electrified.

EXPERIMENT II.

THE same cork suspended by the magnetic virtue as in the other experiment, when placed in a large receiver exhausted of air, will not have the least rotatory motion, although it be as near the same electrified point as before. But immediately upon suffering a small quantity of air to enter the receiver, the cork will turn round, and continue to do so if the point be continually electrified.

PROPOSITION XXX.

ELECTRIC bodies may be rendered non-electric by heat.

Proof by Experiments.

THIS is the case with wax, pitch, rosin, or glue, when melted. For if in a large iron ladle any of those bodies be thoroughly melted, and the ladle be afterwards suspended with a silk line, or laid upon wax, there being a wire, or some non-electric body so placed, as to conduct the electric matter from the iron bar to the center of the surface of the melted matter, the ladle will be electrified; and an explosion may be produced both from the ladle and the melted matter. But as they grow cold they will be less and less electrified: And when they

are quite cold, there will issue no explosion from either of them ; nor will light bodies be moved towards them, as before they would.

EXPERIMENT II.

To a glass cylinder G (fig. 20.) open at both ends, eight inches long, and about three wide, I fixed at one end a metal plate m, with a strong cement, of such a nature as that the cement would require a greater heat to melt it, than is requisite to melt either rosin or beeswax. This I did to prevent some melted rosin, which I intended to pour in soon after, from running out of the bottom of the glass. Into this cylinder I let drop a small piece of metal red hot, in order to keep the melted rosin when poured into the cylinder G from chilling too soon at the bottom. I set the metal plate, and cylinder thus prepared on the earth, and then filled the cylinder with boiling rosin (the surface of which communicated with the bar by means of the wire w) upon turning the wheel and bringing my hand towards the bar no explosion ensued ; though the bar was sufficiently supplied with electric matter, as appeared from the explosions when the wire was taken away. After staying some time till the heat of the rosin was somewhat abated, the electric matter began to appear in small explosions on my approaching the bar, and as the heat

heat still decreased the explosions grew stronger; till at length when the rosin was become quite stiff, the explosions were as strong as when the wire and glass were removed from the bar.

EXPERIMENT III.

INTO a coated vial of the same kind with that we have all along made use of, I poured some melted rosin (the vial being first made gradually hot to prevent it from breaking) till it was nearly filled, and put the wire w into it, then taking hold of the covering of the vial, I electrified the melted rosin that was within the vial, and on compleating the circuit, there issued a large explosion; attended with a convulsive shock. As the heat decreased, the explosion and shock became gradually less; till at last I was not able to cause any explosion or shock by compleating the circuit.

EXPERIMENT IV.

GLASS, when heated much, is also a non-electric. This I tried at a glass-house by various experiments in the following manner.

HAVING fixed the electric apparatus M, and ordered the wheel thereof to be continually turned, that the electric matter might be continually supplied to the bar, I desired one of the workmen to take out of the furnace as much of the hottest melted glass with an instrument they call a blowing-iron or pipe, as

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would cover the end thereof four or five inches thick, and to deliver it to another workman who stood upon a board supported by bottles. This last person was continually electrified by means of a wire which passed from the iron bar to him, and that in a very strong degree, before he took hold of the blowing-iron with the hot glass at the end of it. On my approach towards the thickest part of the melted glass, with a bar of iron, an explosion ensued, and that as often as I approached it. But the explosion became weaker as the glass cooled, till at length no explosion could be produced.

EXPERIMENT V.

I NOW laid the bar of iron in my hand upon the thickest part of a fresh quantity of melted glass, and approaching with my other hand the blowing-iron which was held by the person standing on bottles, no explosion ensued: but as the glass cooled, the electric matter began to appear in explosions from the blowing-iron; which explosions increased in loudness and light as the glass grew colder.

EXPERIMENT VI.

A PERSON who was continually electrified from the bar took hold of the blowing-iron, on which was gathered a fresh quantity of melted glass. Immediately to this I applied a piece of iron, and drew out from the glass a slender
thread

thread of above four feet in length. During all the time of drawing it out, no signs appeared of there being any electric matter in the person. But soon after (for the thread of glass was presently cooled) the person was strongly electrified.

EXPERIMENT VII.

I ORDERED another piece of melted glass to be gathered, nearly equal in quantity to the former, and having electrified the filings in the vial to the greatest degree, I placed the melted glass (which was better than four inches thick round the end of the blowing-iron) so as to make up a part of the dissipator. (See fig. 21.) Upon completing the circuit, an explosion ensued, and near the whole quantity of electric matter was dissipated; in like manner as when the circuit is completed with a bar of iron, or a wire only. But these effects were not produced when the glass became colder; even though the glass was not a quarter of an inch in thickness.

EXPERIMENT VIII.

I REPEATED this last experiment, but did not electrify the filings in the vial so strongly, and instead of completing the circuit with metal, I did it with my hands, when I felt the usual painful sensation and convulsive shock in my arms and across my breast.

EXPERIMENT IX.

I TRIED the same experiments with a large piece of heated amber, instead of melted glass, and found the effects to be much the same as in the foregoing experiments.

UPON the whole of these experiments, doth it not seem, that, was spirit of turpentine, or lintseed oil, and many other fluids, to become hard and dry solids, they then would become strong electrics? *M. Boyle*, found by evaporating about a fourth part of good turpentine, that the remaining body, when cold, hardened into a transparent gum, almost like amber, which proved electrical: and by mixing two such liquors as *petroleum*, and a strong spirit of nitre, and then distilling them, he obtained a brittle substance, as black as jet, which also was an electric. He likewise found that a glass made of the ashes of antimony, and also a glass made of lead without any addition, had the same electrical properties with other glass. The glass of lead, he observes, might easily be brought again to afford malleable lead, which is a non-electric body. See his *Mechanical Production of Electricity*.

By boiling turpentine and water together, which are two non-electrics, an hard transparent substance is produced called Colophony. This will move light bodies like amber upon friction;

friction; but if it be reduced into a fluid state again by melting, then it becomes a strong non-electric: as appears from its conducting the electric matter to other bodies, in like manner as iron, lead, or any other metal.

PROPOSITION XXXI.

SUCH solid bodies as are exceedingly elastic, and whose surfaces are smooth, regard being always had to the light which enters their composition, act more strongly and uniformly upon the electric matter, as well as upon light, in refracting and reflecting it, than bodies that have those properties in a less degree, and whose surfaces are not so even.

FOR a diamond, which is a body highly elastic, is also highly electric, and it reflects and refracts light more copiously than any other body. Glass is not so hard as a diamond, it is therefore probable, that it is less elastic; and we are certain that it is not so highly electric: nor does it reflect and refract light so copiously as a diamond.

WAX, though a body of a different nature from vitreous bodies, yet agrees with those bodies in being an electric, and repelling the electric matter. It is not so strong an electric as glass, though its refractive power exceeds the refractive power of glass considerably; one

reason of which may be its want of hardness. For glass, as well as wax, when brought into a liquid, or soft form, become non-electrics: and as they cool and recover a solid form, they become again electrics. See proposition xxix. Another cause of the difference between electrical bodies in their effects, may be the different smoothness of their surfaces, for the surface of a diamond is much smoother than the surface of glass; as may be gathered from its reflecting and refracting light more copiously, because the rougher any substance is, the less regularly will light be reflected from it. If this be true, with respect to light, why may it not in some degree hold true with respect to electric matter?

FROM the same principles we may explain the difference between a diamond and amber: for was amber equally hard with a diamond, it is probable it would be a much stronger electric than a diamond; as its refractive power, in proportion to its density, is superior to the refractive power of a diamond, in proportion to its density.

PROPOSITION XXXII.

ELECTRIC matter may be accumulated in electric bodies.

FOR, when a diamond is rubbed in the dark, it appears luminous, and attracts and repels light

light bodies, and these effects continue for some time after the rubbing ceases, which could not be the case, if electric matter was not accumulated within it^a. How the electric matter is accumulated within the diamond, may be understood from proposition xvi. For by friction the *atmosphærule* of the diamond, and of the rubber, which are in contact with each other, are both rarified, whence the electric matter flowing from the rubber, must pass with ease from it into the diamond. But the *atmosphærule* on the other side of the diamond not being rarified, at least to that degree, the electric matter cannot pass out of the diamond so easily as it passes into the diamond: and therefore may be accumulated.

^a Let a large diamond be cemented to the end of a cylinder of glass, or wax, eight or ten inches long, and upon a cake of wax let there be placed a cushion which is made of hair and silk. If a person takes that end of the cylinder of glass in his hand, which is farthest from the diamond, and rubs the diamond upon the cushion, the diamond will not appear so luminous, neither will it act so strongly upon light bodies, as when it is rubbed upon a non-electric.

THE effect, with respect to the electric matter's acting upon light bodies, is much the same, if, instead of a diamond, amber be made use of after the like manner; and it is probable, was amber equally transparent with a diamond, it would appear equally luminous.

THE same effects are observed, though in a lesser degree, upon rubbing glass. The reason why these effects are not so strong, seems to be, that the *atmosphærule* of glass is not strong enough to confine it within the body, but suffers it to pass out more freely than the diamond.

THAT the accumulation of electric matter in bodies electrified arises from the resistance being less where the electric matter enters than where it passes out, may be farther illustrated from what follows.

EXPERIMENT.

IF the glass G (fig. 1.) be exhausted of air, and afterwards rubbed with a hand or cushion, the inside of the glass will appear luminous.

THE reasoning made use of in the xvith and last propositions, seems to hold equally true here; for the resistance on the outside of the glass, which arises both from its *atmosphærule* and the surrounding air, being greater than on the other side of the glass, when the air is taken away, the electric matter should pass where the resistance is least, and this appears to be the case in the exhausted glass.

IF it be supposed otherwise, to wit, that the electric matter accumulated between the pores of the glass, passes out into the air, surrounding the outside thereof as readily, or nearly so, as
into

into the exhausted cavity ; in such case the resistance given to its exit out of the glass arising from the *atmosphærulæ* of the air and glass, ought not to be greater than in the other case. But this seems to be otherwise ; for the accumulated electric matter in the pores of the glass, passing from thence into the exhausted cavity of the glass, is opposed by the *atmosphærule* of the glass only : whereas the outside is opposed by the *atmosphærule* of air as well as glass ; and air, we have shewn, actually retards or opposes the passage of electric matter, as well as the *atmosphærule*. Therefore such a supposition cannot be true.

THIS seems to be farther manifested from the following experiment. For, if during the rubbing of the exhausted glass, light bodies be brought near it, such as pieces of leaf gold, down, feathers, &c. they will not be acted upon, and moved towards the glass so strongly, as they otherwise would, was the glass not exhausted.

QUERY. Whether this luminous appearance on the inside of the exhausted glass is not most visible when the air therein is rarified to a certain degree ?

PROPOSITION XXXIII.

WHEN a non-electric body, which is not electrified, is made to approach so near to one electrified, that the force arising from the elasticity of the electric matter within the body is greater, in that particular part of the body (by its endeavouring to pass into the body which is not electrified) than the force arising from the elasticity of its *atmosphærule*, it will pass off with a sudden motion, and be condensed more and more as it approaches the electric body ; till at length an explosion follows.

FOR as soon as the elastic force arising from the accumulated electric matter is sufficient to overcome the elastic force arising from the *atmosphærule*, by which the electric matter is retained in the body, and the least quantity thereof moves towards the approaching body, the force with which it tends to the latter, increases every instant, and causes a greater condensed focus of that electric matter, whilst the force arising from the *atmosphærule* decreases ; consequently the electric matter must pass off suddenly, and not by degrees : and after coming into the air between the bodies, cause an explosion by virtue of a sulphureous matter that is carried along with it. See corrol. ii. prop. xvii.

SECTION

SECTION XIII.

PROPOSITION XXXIV.

THE electric matter passes both into and out of bodies which have points, edges, or angular terminations, more readily than it does into, and out of bodies of the same kind which have no points, edges, or angular terminations.

THE truth of this is manifest from several experiments following the viith and xxii^d propositions.

PROBLEM.

LIGHT bodies moved to a body electrified, may be detained there by apposing fine points or edges to them at a considerable distance: and if blunted or obtuse points or edges of the same kind be apposed at the same distance, those light bodies will be no longer detained, but will recede from the electrified body. And upon apposing fine points or edges again, the light bodies will be forced back again to the electrified body.

EXPERIMENT I.

^a AT a foot distance (or thereabouts) from the bar BB (fig. 22.) hold a feather, or a piece

^a Mr. *John Canton* made several curious experiments of the same kind with this.

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of down D, and when it leaves the hand, or is moving towards the bar, appose the point of a needle, which is not electrified, at fifteen inches, or a greater distance from the bar; but so that the down D may be between the bar B B and the point of the needle P. The down D, in this case, will be driven quicker and closer to the bar B B than if the needle was not apposed: and the down may be detained there for any time by continuing to hold the needle in the same position; notwithstanding the electric matter moves from the bar B B to the needle P. See observ. v. prop. 7.

EXPERIMENT II.

HOLDING the needle at the same distance as before, turn it, so that the eye or head thereof may point towards the bar B B, and the down D, and immediately on doing this the down will be no longer detained at the bar, but will recede or drop from it.

EXPERIMENT III.

TAKE two downy feathers, as nearly equal in size and weight as can be had, and place them at such a distance from the bar B B, as that the electric matter issuing from the bar shall be able to move them towards the bar; and let one of those feathers be separated from the other two feet at least. Then when the feathers begin to move towards the bar, let the
point

point of a fine needle be apposed to either of them; immediately on doing this, the feather, to which the needle is apposed, will be driven to the bar, and detained there: whilst the other, instead of approaching the bar, will recede or fall down, and remain unmoved, while the needle is held in the same position.

N. B. IN these three last experiments, we suppose the wheel to be continued turning all the time.

TO explain these phænomena from the principles we have been endeavouring to establish:

SUPPOSE an elastic medium to be diffused through any given space, and a cone BBP (fig. 22.) to be formed therein by the motion of particles of the same kind propagated from the surface of a body BB (situated in a part of that space) in such a manner as afterwards to tend to a point P. The action of a fluid thus moving and constituting the cone, will cause the elasticity of the particles surrounding it to become greater, consequently the fluid will be denser on the outside of the cone than in any part of the cone itself. And it will be rarer at the center of the base of the cone than in any other part of the cone: and in receding from the base to the vertex, its density continually increases. A light body then placed in the cone, cannot

cannot pass out of it into the circumambient condensed fluid, but must be forced close to the center of its base; notwithstanding the motion of the fluid is contrary, to wit, from the base to the vertex. Now, why may not the *æther* be the elastic medium diffused in the manner supposed above, and the needle's point be considered as the vertex of such a cone whose base lies at the electrified body BB. The electric matter then will be densest at the point of the needle P, less dense between the needle's point and the bar BB, and rarer still at the bar BB, consequently the down D, or any other such light body, when placed between BB and P, must be forced to the electrified bar BB; detained there, and pressed in a manner close to it, so long as the needle is held in the same position, and the body is continued to be electrified.

HENCE may be seen the reason why both the feathers mentioned in the third experiment do not exhibit the same phenomenon.

IF an obtuse or broader pointed body (which must now be looked on as the section of a cone) be apposed, as in the second experiment, as the surface is hereby increased, the area of the *atmosphærule* will be larger likewise; and the resistance arising from it will be greater (see prop. ii.) therefore the electric mat-

ter will not tend towards it with so great a force as in the other case, because it cannot dissipate so fast by this obtuse point; but must pass off in other places where the resistance is less, by proposition vii. and xvi. Now as all action between bodies is mutual and equal, and only a small quantity of electric matter passes towards the obtuse point, the force arising from this small quantity must be weak and insignificant; and the force with which the down will be repelled from it to the electrified body will be so too: nor can it possibly, as in the other case, be forced back towards the electrified body (unless the obtuse point be moved nearer it) for the repelling force arising from the electric matter in this case will be greater between the feather and the electrified body, than between the feather and the obtuse point.

WHAT has been said already in regard to pointed bodies, we think, may be sufficient for explaining the various phænomena producible therefrom: we shall only mention two or three experiments more of this kind, which are equally surprising, and leave the application of them to the reader.

EXPERIMENT.

IF a very fine downy feather F (fig. 23.) with long fibres, be fixed upon the bar BB, and electrified, the fibres will be stretched out
in

in many directions, all of them receding from one another. Now if a person stands on the floor at the distance of two or three feet (nay sometimes more, when the machine electrifies strongly) holding a needle N, finely pointed, with the point towards the feather F, the fibres thereof will be forced close together (as if they were pressed) but always most on that side which is nearest the needle. If the person, instead of standing on the ground, stands upon wax, the effects will be weakened greatly.

EXPERIMENT.

AGAIN, if the person standing either on the floor or on wax, turn the needle, so that the head thereof may point towards the feather, the fibres will then recover nearly their first form, or position, and be stretched out again in many directions, without any other change of circumstances. But if the head of the needle be brought considerably nearer the feather, then the same phænomenon will insue as happens from the fine points, though in a weaker degree.

EXPERIMENT.

IF a down feather, of the same kind with that made use of in the last experiment, have a thread four or five inches long fastened to it, so that the thread may hang from the feather as many inches, the feather will be moved to the bar, and be suspended; where it will continue

tinue whilst the bar is continued to be electrified. But if a person who is electrified with a pair of scissars in his hand clips the thread off, the feather will immediately fall, or be repelled from the bar.

SECTION XIV.

PROPOSITION XXXV.

LIGHT bodies, such as down, leaf gold, leaf silver, &c. which in the open air are moved or forced to bodies electrified, will not be affected in like manner in *vacuo*, nor when the air is confined: provided the vessel in which the light bodies and the electrified body are put, be set upon an electric body.

EXPERIMENT.

SUPPOSE C (fig. 24.) to represent a glass cylinder, to both ends of which A and B^a are closely cemented two plates of metal. On the plate B is screwed a stop-cock. Set this cylinder, having first exhausted the air, and dried

^a N. B. The plates A and B should be cemented to the glass, and not laid on with wet leather, unless it be with oil; but even that must be used sparingly, because the moisture may adhere to the sides of the glass, and thereby prevent the experiment succeeding.

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the glass very well upon wax w, standing upon the end A, there being first some very light body laid within the cylinder at the bottom A, and the in and out side of the cylinder being well dried; then let a person standing upon an electric, take hold of the moveable wire M, which is so contrived as to be pushed up or down, as occasion may require, without admitting the air. In such circumstances, the person and wire being both electrified, the leaf gold will not be raised from A, even though the wire M be moved extremely near to it. Nor does letting in the air seem to make any kind of difference.

N. B. WE have not been able to find that cylinders of different lengths, or different diameters, produce different effects from what was observed in the last experiment. For upon making use of a cylinder two inches wide and forty inches long; and another of ten inches wide and fifteen deep, the leaf gold placed at one end, would remain there, though the electrified wire M was moved very near to it in each experiment.

PROPOSITION XXXVI.

LIGHT bodies, such as down, leaf gold, leaf silver, &c. when placed in a glass vessel which stands upon a non-electric, will be differently

ently affected by an electrified body, placed likewise in the same vessel in air and in *vacuo*. In air, they will be moved towards the electrified body, and in *vacuo* they will not.

EXPERIMENT I.

INTO a cylinder of glass, eighteen inches long and eight inches in diameter, I put a little leaf gold; and afterwards cemented a plate of metal to each end of the cylinder: one of those plates had a stop-cock fitted to it; and in another part of the same plate there was a collar of leathers, through which was put a wire of a considerable length. But before the plates were cemented, I hung a small ball of metal to that end of the wire which was within the cylinder. Then setting that end, at which the leaf gold was laid, upon the ground; after having exhausted the glass, I electrified the other end, by letting a chain, which hung to the bar, communicate with the brass at the upper end of the glass; whilst at the same time I stood upon wax, and held in my hand the end of the wire which passed through the collar of leathers. Upon moving the ball nearer to, or farther from the leaf gold, as I thought proper, I did not find in any of the trials that the leaf gold ever left the bottom plate: though I was convinced in every trial, from the explosions which were caused sometimes from myself, and at

others from the wire, by the approach of a non-electric body, which was not electrified, as well as from other effects, that there was more than a sufficient quantity of electric matter in the electrified ball to move the leaf gold.

EXPERIMENT II.

HAVING an opportunity of trying the last experiment with a glass of a larger size, and of the shape represented by the 25th figure, it being about fourteen inches deep, and about twelve inches wide in the broadest part, I repeated the experiment; but, instead of cementing the metal plates, I moistened a leather for each plate with a little oil, and instead of removing the glass from the air-pump, as was done in the last experiment, I continued it upon the pump, and caused a chain which was fixed to the bar to communicate with the wire and ball in the glass. Upon turning the wheel, and observing the degree of strength of the electrifying power in the wire, I found the experiment to succeed in the same manner as was mentioned in the last experiment.

EXPERIMENT III.

UPON letting in part of the air, the leaf gold immediately moved from the bottom towards the electrified ball, but not so vigorously as when the whole air was let in: but even in this case the motion of the light body towards the elec-

fied body, did not appear altogether so vigorous as in the open air.

THE reason why the leaf gold was not moved in the first and second experiments, seems to be that the sides of the glass were more strongly electrified when the air was taken away, than when it was not; for when the sides of the glass are electrified, they may disturb the force which would otherwise cause the leaf gold to move towards the electrified ball, and that disturbance must be greater or less, as the sides of the glass are more or less electrified. For equal and contrary forces always destroy one another.

THIS reasoning seems to be in a great measure confirmed from the different effects produced by glasses of different diameters.

EXPERIMENT IV.

FOR upon making use of a tube of glass eighteen inches in length and two in diameter, and another of four feet in length and two inches in diameter, I found that the leaf gold remained at rest when the air was taken away; and that on letting in part of the air, or indeed the whole quantity, no apparent alteration was made; for the leaf gold continued unmoved in all these cases.

EXPERIMENT V.

UPON making use of a cylinder three feet in length and four inches in diameter, the other circumstances being the same, I did not find any difference in the experiment, whether the air was exhausted or not, excepting a very weak trembling motion of the leaf gold, which was observed in both cases.

EXPERIMENT VI.

ON trying the same experiments with a cylinder of glass eighteen inches long, and five inches wide : the leaf gold appeared to be affected very near alike, whether the air was taken away or not. For when the air was taken away, the leaf gold seemed to shew the like trembling motion as mentioned in the fifth experiment; and when the air was let in, that motion seemed not much increased : but the leaf gold never left the bottom of the cylinder in either of these cases.

IN these last experiments, when the several cylinders were exhausted, I tried whether their outsides were electrified; and if they were, whether letting the air into the cylinders made any difference. I found that their outsides were electrified, and more highly so when the air was taken out of the cylinders than when it was not.

I LIKEWISE tried whether an explosion could be produced in *vacuo* with the same success as in air; and found that when the air was taken away, there was no explosion.

PROPOSITION XXXVII.

A LIGHT body may be suspended between two bodies, the one electrified, the other not, in such a manner, as that it shall not touch either of them: and shall always be farther from the electrified body than the body which is not electrified, whether they be inverted or not. And the distance from the electrified body will be always greater or less, as the two bodies are more or less electrified.

EXPERIMENT I.

IF leaf gold, leaf silver, or any other light body, G (fig. 26.) be held near a plain of metal P, which is electrified, it will be moved towards the plane; and when G becomes equally electrified, it will recede from P (see experim. vii. sect. iii.) But if another plane of metal P, which is not to be electrified, be held parallel to P, at about six or eight inches distance, so that G may be between them (nay, sometimes at a much greater distance) the light body G will be suspended between the two planes P and p. And if P and G are electrified to a great degree, the distance of G from P may be

made greater than when they are electrified to a less degree.

EXPERIMENT II.

IF a person standing on wax, holds the plane *p* in his hand, the distance at which *G* will be suspended from *P*, decreases as the person becomes more and more electrified: this appears from the person's being obliged to move the plane *p* nearer *P*, in order to keep the body *G* suspended. But when the person and the plane *p* becomes equally electrified with *P* and *G*, then *G* will not be suspended, but remain at rest.

IN order to explain these experiments, let us suppose the electric matter in a body, as it rushes out on the *æther* surrounding it, to form a kind of atmosphere, which is of greater or lesser extent as the body is more or less electrified (see experim. vii. sect. iii.) When therefore two bodies are electrified to a great degree, the diameters of their atmospheres (if they may be so called) and the resistance arising from them will be greater, than when they are electrified to a small degree, and consequently the greater will be the force with which they recede from each other. Now, if two bodies of unequal weights, suppose *P* and *G*, be equally electrified, and a third, which is not electrified, suppose *p*, be apposed, as in the first experiment:

In

In such circumstances we find that G will be suspended. And it will be nearer the non-electrified body p than the electrified body P : because the resistance arising from the *atmosphærule* of p, is less than the resistance arising from the electric atmosphere of P. And this is farther confirmed from observing that upon electrifying p equally with P, as in the second experiment, G continues no longer suspended, but falls down by the force of gravity, the forces arising from the electric atmospheres of P and p, being now equal, and destroying each other.

NOTE, If G be very light, it may be suspended without the assistance of the plane p, provided some other non-electric body be within four or five feet of the plane P, towards which non-electric G will always tend. The reason we have given before, seems to hold equally true in this case ; for as the air may be electrified, and G tends towards the non-electric, the resistance arising from the *atmosphærule* of the air and the non-electric must be less than the resistance arising from the electric atmosphere of P. This is likewise confirmed from observing, that upon removing the non-electric to a much greater distance, G no longer continues suspended.

EXPERIMENT.

IF two, three, four, or more pieces of leaf gold, leaf silver, or any other light bodies, be placed between the two planes P and p, as in the first experiment, when P is electrified they will be suspended between the planes, but at a considerable distance from each other. For the atmosphere of electric matter surrounding each piece, repels its neighbour, and prevents them coming together, or approaching nearer to one another, though their several distances from p, are nearly equal.

N. B. IN the making of this experiment, when the turning of the wheel, or the supply of electric matter is not equal, sometimes two or more pieces of leaf gold will approach one another, and endeavour to form one continued line or stream of non-electric matter from P to p, by which means the electric matter will flow more readily from P to p; and oftentimes at that instant, most, if not all, of the other suspended bodies drop down and remain at rest.

WE have proved, that under certain circumstances, thin electric bodies resist or oppose the entrance of electric matter less than bodies of the same kind that are thicker.

WE have likewise shewn, that upon heating electric bodies they are rendered non-electric.

QUERY.

QUERY. May not these different effects observed between thick and thin electrics of the same kind ; for instance, thick and thin cakes of wax, arise principally from the different quantities of light contained within different quantities of the same matter ?

AND may not the different effects observed in electric bodies, when moistened, heated, or made fluid, from what are observed in the same bodies not affected by moisture or heat, arise from some change in the *atmosphærulæ* of the bodies, or in the texture of the parts of the bodies themselves ?

PROPOSITION XXXVIII.

IF a given quantity of electric matter was to pass directly through any number of bodies of the same kind, placed in a right line of a given length, so that their diameters may measure the whole length of the line, the resistance given to its passing through them will be least when their diameters are the greatest, and greatest when their diameters are the least ; or in other words, the resistance will be least when it passes through the least number, and greatest when it passes through the greatest number, both measuring the same length.

FOR if the resistance given to the exit or entrance of the electric matter in non-electric bodies, arises only from the *atmosphærulæ* surrounding

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rounding them : and if the resistance is the same in bodies of the same kind, whether they are large or small : it is evident the lesser number of bodies the electric matter passes through, the lesser also must be the number of *atmosphærulæ*, and consequently the lesser the resistance. But we have shewn that in bodies of the same kind, whether they are large or small, the resistance arising from their *atmosphærulæ* is the same.

To illustrate this, let A, L (fig. 27.) represent the line given, B, C, two spheres, and a, d, a, v, the *atmosphærulæ* surrounding them. If now a particle of matter be supposed to pass along A L through B and C, it must pass through four *atmosphærulæ* only, to wit, a, d, a, v ; whereas there would be many more for it to pass through were there a greater number of bodies of smaller diameters placed in the same line^a.

Now the larger the body is, which a given quantity of electric matter is to be expanded in, the more that quantity will be rarified (see

^a Since the refractive power of air is continually the same in all parts where the density is given ; and as electrical experiments are for the most part made in spaces where the density of the air differs very little, the force which resists the entrance of the electric matter into the particles may be supposed equal in the several particles.

experim. ix. sect. iii.) and the more it is rarified the less it will oppose the entrance of a fresh supply of electric matter. Hence we may gather the reason, why the electric matter in a body may have a stronger tendency to pass into gross bodies, such as gold, silver, lead, iron, brass, copper, tin, and all other metallic bodies, moist and fluid substances, and more particularly into the earth itself, than into dry air.

THAT air resists the passage of the electric matter will be farther illustrated from the following experiments.

EXPERIMENT I.

To each end of a hollow cylinder of glass G, about eighteen inches long (fig. 28.) and about five inches diameter, let there be fixed with cement two plates of metal B and C: through a hole in one end, suppose B, in which there is a collar of leathers, a wire w is to pass, which may be moved higher or lower at pleasure, in like manner as was directed in the experiment following the xxxivth proposition. Let there be likewise on the outside of one of the ends a stop-cock to screw on to an air-pump, in order to extract the air out of the cylinder. In such circumstances either end of the cylinder may be electrified. Now upon electrifying either end (the room being dark) when the air is not exhausted, no light will be seen to pass from
the

the wire *w* to the opposite end of the cylinder *C*, or from *C* to the wire *w*; whereas, if the air is exhausted, and *B* is electrified, then a stream of light appears to pass between the wire *w* and the opposite end *C*, representing a cone, whose apex is at the end of the wire *w* at *D*, and the base at *C*.

EXPERIMENT II.

LET one end of a thin tube of glass (fig. 29.) two or three feet in length, and two or three inches in diameter, be hermetically sealed, for example, at *A*; and to the other end *B*, let there be fixed a stop-cock, and let a straight wire *BC*, six or eight inches long, be fixed to *B*, so that it may lie in the axis of the tube. Now, if the tube exhausted of air, be suspended with silk lines, and afterwards electrified, upon holding a non-electric body at the end *A*, a light will issue, which will seem to pass from the wire towards *A*, even though the distance be more than two feet, and the *atmosphærulæ* of the outer and inner surface of the glass are interposed between the wire and the non-electric body without.

S E C T I O N XV.

HITHERTO we have been endeavouring to establish certain principles from experiments and observations. And though all of them may not be strictly true, yet we hope that most of them may assist others in their inquiries after truth. What follows is an application of those principles towards explaining the cause of gravitation, and some other phenomena. I am sensible that many may esteem this an extravagant undertaking: but as every attempt to promote useful knowledge is truly laudable; and what I have delivered is proposed only as queries; I hope it will meet with that indulgence and candour, which are the inseparable attendants of distinguished sense and learning.

PROPOSITION XXXIX.

SINCE gravitation is supposed to depend upon the graduation of the density of the *æther*, it follows, that the more that density is increased, the greater will be the force of gravitation.

IF the *æther* be diffused, as Sir *Isaac Newton* supposes, this proposition is self-evident.

PROPO-

PROPOSITION XL.

IF *æther* be accumulated within a body, and the *æther* surrounding that body be equally dense, and afterwards passes out from all parts of the body equally, the density, and consequently the pressure of the surrounding *æther* will be increased; and this increase of density will be greater or less, as the quantity passing out is greater or less: and will continue so long as the *æther* continues to pass out of the body.

IF we are able to accumulate the *æther*, then this proposition is also self-evident.

PROPOSITION XLI.

IF *æther* be accumulated within a body, and the density of the surrounding *æther* be greater on one side of the body than it is on the other, the accumulated *æther* will pass out in the greatest quantity where the density of the surrounding *æther* is least, and in the smallest quantity where the density of the surrounding *æther* is greatest: or in other words, the accumulated *æther* will pass out in the greatest quantity where the resistance is least, and in the smallest quantity where the resistance is greatest: consequently if the *vis inertiae* of the body be less than the difference of the pressure of the *æther*, or than the resistance on any two
sides

sides of the body in any instant, it will be moved towards that side, and in that direction where the pressure upon the body, or the resistance is least.

FOR, if pieces of leaf gold, sand, powdered glass, rosin, or any other light bodies, A, whether non-electrics or electrics, are electrified, and placed near a large non-electric body B, which is not electrified, they will move towards it with great rapidity. And if any other body, which is something larger, be electrified and suspended in a string, so that it may hang in the same horizontal line with the non-electric, which is not to be electrified, the suspended body will move from its natural point of rest, and tend towards the non-electric body, which is not electrified. The resistance on the side of A, next B must be greater than the resistance on the side of A, which is farthest from B, from the *æther's* being rarer between bodies than without them. But the expansive force in the accumulated *æther* within A is equal in every part, therefore A must move towards B.

PROPOSITION XLII.

IF when *æther* is accumulated within a body B, part of it be supposed to pass from it into another body A, in which the *æther* is not accumulated; the body A will begin to move
when

when the difference of the pressure of the *æther* on any two of its opposite sides becomes greater than its *vis inertiae* : and it will move towards that side where the pressure, or the resistance is least.

EXPERIMENT.

LET a bar of iron represent the body B, and be electrified, upon bringing near to the bar pieces of leaf gold, sand, powdered glass, rosin, or any other light bodies, whether non-electrics, or electrics which are not electrified, they will move towards the bar with great rapidity. And if any other non-electric body, which is not electrified, be suspended in a thread, so that it may hang in the same horizontal line with the electrified bar, it will move from its natural point of rest, and tend towards the electrified bar.

FOR B, in this case, from its *vis inertiae* being greater than the difference of the pressure of the *æther* on its two opposite sides, cannot move towards A. But the accumulated *æther* in B can pass into A, as there is no accumulation of *æther* in A, and may be there accumulated : and the greater the accumulation is, the greater will be the resistance. This accumulated *æther* in passing from A into the *æther* surrounding it, must cause a greater density or pressure upon the remote side of the body. A, for example,

at x (fig. 30.) than on the nearer side into which the *æther* passes from B. And from this increased pressure, A must of necessity approach towards B.

If the *æther* continues to pass from B into A, and does not pass out again so readily, the accumulated *æther* in A will at length become equal to the accumulated *æther* in B: because A will receive continually the *æther* from B, till the expansive force of the accumulated *æther* in A becomes equal to the expansive force of the accumulated *æther* in B. And when that happens, both bodies must be equally electrified.

PROPOSITION XLIII.

WHEN the *æther* is denser between bodies than without them, so that the difference of the density exceeds the *vis inertiae* of the bodies, they will recede from one another.

Now, when two bodies, suppose those mentioned in the third section, experiment vii. are equally electrified, the *æther* must be denser between them than on their outsides. For the *æther* cannot pass from A into B, or from B into A, whilst the bodies continue equally electrified. And it appears from experiment, that the *æther* does pass out at their remote sides, which it could not do if the *æther* was not rarer, con-

N. frequently

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frequently the resistance is less on the outside of the bodies than between them; therefore if the *vis inertiae* of either, or both, be less than the difference of the density of the *æther*, they must of necessity recede from one another.

THE truth of the preceding propositions contained in this section, may be confirmed by a great variety of experiments. But as they are all pretty nearly of the same kind with those already mentioned, and as they all seem to be explicable by the same principles, I shall only set down a few of the most material ones.

EXPERIMENT I.

SUPPOSE A and B (fig. 31.) to be small equal balls of cork or metal, suspended in lines of silk, fifteen or twenty inches long, and hung at about six or eight inches apart. If one of them, for example, A be electrified, they will both move towards each other, and when the density of the electric matter in one, becomes equal to the density of the electric matter in the other, they will recede from each other.

EXPERIMENT II.

IF the same balls be suspended with thread instead of silk, and one of them, for example A, be suspended on a non-electric body which is electrified; whilst the other body B is suspended on a non-electric, which is not to be electrified;

they will move towards, but never recede from each other, whilst any considerable quantity of electric matter remains.

THE difference observed between this and the last experiment, is owing to the line and the body to which B is suspended, which in this case are conductors of the electric matter. For the electric matter passing into B, is conveyed by the thread into other non-electrics, and as fast as B receives it from A : so that there can be but very little if any difference between the density on the inside and on the outside of the bodies.

EXPERIMENT III.

IF the electric body A be suspended with thread, and the other body with silk, then B will move towards A, and A towards B: and when B becomes equally electrified with A, both will be repelled.

THIS last experiment is the same in the effect with the first, only that the electrified body is suspended with thread instead of silk.

EXPERIMENT IV.

IF A be suspended by a silk line upon the bar, and be electrified by means of a wire, which is to be removed as soon as A is electrified : and B be suspended by a thread line on a non-electric body, which is not to be electrified, they will move towards each other. On

their near approach, the greatest part of the accumulated electric matter in A will be dissipated, and in a very short time both A and B will recover their natural points of rest.

FOR A having at first but a small quantity of accumulated electric matter, and when it loses any part thereof, being incapable of receiving more from the bar on account of the interposition of the silk line, so much electric matter as enters B will immediately pass by the thread into other non-electrics.

EXPERIMENT V.

IF a large non-electric body be laid upon an electric, and afterwards be electrified, a light body B, placed near, will be first moved towards, and afterwards driven from it.

THIS last experiment is similar to the first.

EXPERIMENT VI.

IF A be not electrified, and the light body B placed near it be electrified, it will be moved towards A: and upon its very near approach to A, will cease to be electrified.

ACCORDING to the before-mentioned law of the *æther*, its density in any body (supposing the density of the *æther* in a body to be inversely, as the density of that body) will be exhibited in the following table. As also the proportion of the pores to the solid parts in the same bodies.

THE theorem from which the proportions of the pores to the solid parts were got, is the theorem by which Doctor *Robinson* composed a table of the same kind, published in his *Appendix* to his *Dissertation on the æther*.

$\frac{41.244 - \Delta}{\Delta}$ the measure of the pores to the solid

parts was thus found. Let the pores to the solid parts, or the space possessed by the pores of a body to the space possessed by its solid parts, be as P . to 1 . Then $P + 1$ will express the whole space possessed by the body, or the magnitude of the body. The quantity of matter in the body is measured by its magnitude and density taken together, that is, 1 is as

$P + 1 \times \Delta = P\Delta \times \Delta$, whence Δ is as $\frac{1}{P+1}$. The

specific gravity of fine gold by the table is 19.64. The specific gravity of water 1; and Sir *Isaac Newton*, from some observations, thinks gold has more pores than solid parts.

Doctor *Robinson* supposes the pores to the solid parts to be as 11 to 10. or as 1.1 to 1. In gold,

therefore, Δ is 19.64 and $\frac{1}{P+1}$ is $\frac{1}{2.1}$, and to

find the pores to the parts in another body, use this analogy $19.64 : \frac{1}{2.1} :: \Delta : \frac{1}{1+1}$. Now $\frac{19.64}{P+1} =$

$\frac{\Delta}{2.1}$ and $41.244 = P\Delta + \Delta$; and $P = \frac{41.244 - \Delta}{\Delta}$,

the quantity of the solid parts being 1.

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	Specific den- sity of bo- dies, accord- ing to Mr. <i>Boyle</i> and o- thers.	Density of the <i>æther</i> .	Pores to the solid parts
Fine gold	19.640	0.0509	1.100
Standard gold	18.888	0.0529	1.118
Quicksilver	14.000	0.0714	1.946
Lead	11.325	0.0883	2.641
Fine silver	11.091	0.0901	2.718
Standard silver	10.535	0.0949	2.916
Bismuth	9.700	0.1031	3.252
Copper	9.000	0.1111	3.582
Cast brass	8.500	0.1176	3.852
Steel	7.852	0.1273	4.252
Iron	7.643	0.1308	4.396
Tin	7.320	0.1366	4.634
Glass of antimony	5.280	0.1893	6.807
A pseudo-topaz	4.270	0.2342	8.659
A diamond	3.400	0.2941	11.130
Mr. <i>Ellicott</i> found the mean sp. grav. of four Brazil diamonds se- parately; two of them rough coats, and two bright coats to be	3.513	0.2846	10.741
And ten East-India dia- monds of different co- lours to be	3.519	0.2841	10.720
The mean of both	3.517	0.2843	10.727
Clear crystal glass	3.150	0.3174	12.093
Island crystal	2.720	0.3676	14.163
Fine marble	2.700	0.3703	14.275
Rock crystal	2.650	0.3773	14.563
Common green glass	2.620	0.3816	14.742
Stone of mean gravity	2.500	0.4000	15.496
Sal. gem	2.143	0.4666	18.246
Brick	2.000	0.5000	19.622
			Nitre

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	Specific den- sity of bo- dies, accord- ing to Mr. <i>Boyle</i> and o- thers.	Density of the <i>atmos.</i>	Pores to the solid parts.	
Nitre	1.900	0.5263	20.707	
Alabaſter	1.875	0.5339	20.996	
Dry ivory	1.825	0.5478	21.599	
Brimſtone	1.800	0.5555	21.913	
<i>Dantzick</i> vitriol	1.715	0.5831	23.049	
Alum	1.714	0.5834	23.050	
Borax	1.714	0.5834	23.050	
Calculus humanus	1.700	0.5882	23.261	
Oil of vitriol	1.700	0.5882	23.261	
Oil of tartar	1.550	0.6451	25.609	
Bezoar	1.500	0.6666	26.496	
Honey	1.450	0.6896	27.444	
Gum arabic	1.375	0.7272	28.995	
Spirit of Nitre	1.315	0.7604	30.364	
Aquaſortis	1.300	0.7692	30.726	
Serum of human blood	1.190	0.8403	33.658	
Pitch	1.150	0.8695	34.864	
Spirit of ſalt	1.130	0.8849	35.499	
Spirit of Urine	1.120	0.8928	35.825	
Human blood	1.040	0.9615	38.657	
Amber	1.040	0.9615	38.657	
Milk	1.030	0.9708	39.042	
Urine	1.030	0.9708	39.042	
Dry box-wood	1.030	0.9708	39.042	
Sea Water	1.030	0.9708	39.042	
Common water	<div style="display: inline-block; vertical-align: middle;"><div style="text-align: center;">freezing point = 0 boiling point = 100 17 to 18 100 warm</div></div>	1.000	1.0000	40.244
Camphire	0.996	1.0041	40.409	
Bees wax	0.955	1.0471	42.187	
Linſeed oil	0.932	1.0729	43.257	
Dry oak	0.925	1.0810	43.588	

N 4

Oil

	Specific density of bodies, according to Mr. Boyle and others	Density of the <i>æther</i> .	Pores to the solid parts.
Oil olive	0.913	1.0953	44.176
Spirit of turpentine	0.874	1.1441	46.189
Rectified sp. of wine	0.866	1.1547	46.626
Dry ash	0.800	1.2500	50.555
Dry maple	0.755	1.3245	53.628
Dry elm	0.600	1.6666	67.704
Dry Fir	0.550	1.8181	73.981
Cork	0.240	4.1666	170.850
Air	0.00125	800.0000	32994.200

It appears by this table, that the density of *æther* in gold is .0509, in cork 4.1666, in air 800.0000; so that the density of *æther* in cork is above eighty times greater than in gold, and in air, above one hundred and ninety times greater than in cork; consequently the density of *æther* in air is above 15700 times greater than in gold. Hence the density of *æther*, in all probability, is much greater in air, than it is in grosser bodies when they are electrified: that is, when the electric matter is accumulated in them. Whence it seems, that in such bodies the force arising from the increase of density is so very weak, as only to impel light bodies, and those at very small distances; which distances vary as the machine electrifies more or less strongly.

VISION,

VISION, according to Sir *Isaac Newton*, is performed chiefly by the vibrations of the *æther*, excited in the bottom of the eye by the rays of light, and propagated through the solid, pellucid, and uniform capillamenta of the optic nerves into the place of sensation. The several sorts of rays make vibrations of several bignesses, which, according to their bignesses, excite sensations of several colours; the most refrangible rays excite the shortest vibrations, for making a sensation of deep violet. The least refrangible the largest for making a sensation of deep red. And the several intermediate sorts of rays, vibrations of several intermediate bignesses to make sensations of the several intermediate colours.

QUERY. May not this account be farther illustrated from the preceding principles? as thus—

IF the rays of light be bodies of different sizes, the least of which make violet and the biggest red^a: then the largest rays striking

^a Nothing more is requisite for producing all the variety of colours and degrees of refrangibility, than that the rays of light be bodies of different sizes, the least of which may make violet the weakest and darkest of the colours, and be more easily diverted by refracting surfaces from the right course; and the rest as they are bigger and bigger, may make the stronger and more lucid colours, blue, green, yellow and red, and be more and more difficultly diverted. *Newt.*
upon

upon the *atmosphæra* of the *retina* at the bottom of the eye, will act upon a greater portion of that *atmosphæra*, than the rays of light that are smaller. But the more parts of the *atmosphæra* are acted upon by a ray of light, the stronger must be the effect; or in other words, the greater must be the vibrations. Thus it is, the largest rays of light cause the sensation of red, which is the most vivid; and the smallest the sensation of violet, which is the most faint and languid of all colours.

QUERY, As to elasticity, are not all the *phænomena* thereof deducible from the preceding principles, whether bodies rebound or recede from one another by percussion, or when they are forcibly bent, from their own spring they recover their original form and figure? For a fluid, whose particles recede from one another, with a force reciprocally proportional to the distance of their centers, will have its density proportional to its compression (*Newt. Princip. prop. xxiii. book ii.*) when the *æther* is condensed, its elastic force will be increased in the same manner as we find in air, when compressed or condensed. Therefore when the parts of a body are brought nearer each other by any force, such as bending or the like, the *æther* within, and the *atmosphæra* without the body, will be condensed at the same time,

time, and by virtue of the condensation (such force ceasing to act) they will be again made to recede from one another, and recover their former figure.

QUERY, May not cohesion, which is caused by a much greater force than that of gravity, arise from the mutual action of the light, contained within bodies, and of the *atmosphærulæ* surrounding them, the pressure of which *atmosphærulæ* alone may be sufficient to make the particles, when very near or in contact, cohere with a great force, after the manner we have particularly described in pag. If this is the case, the force of cohesion then must be proportional to the *atmosphærulæ* of the particles. Now the *atmosphærulæ* seem to be nearly, as the density of the bodies (See Propositions xx and xxi.) therefore the forces with which the parts of bodies cohere, are nearly proportional to their densities.

“ HENCE the densest particles cohere with
“ the greatest force, and as they lessen in density, so they do in the strength of their cohesion. This force is of the same nature
“ with that of fermentation, for the nature of the particles principally concerned in causing both cohesion and fermentation, are of the acid, unctuous, and sulphureous kind.

C O N C L U S I O N.

THERE have been several hypotheses formed, in order to explain the cause of electricity; some have supposed that the electric matter is lodged within bodies, and such only as are resinous and vitreous; that it lies there in a quiescent state, but ready to fly off as soon as friction has sufficiently agitated the parts, and dilated the pores: and lastly, that the quantity of electric matter contained in such electric bodies, resists and opposes the entrance of the like kind of matter when it is conducted to them from other bodies. Others are of opinion that the electric matter is supplied from the air, and that friction serves only to collect it: while a third set of gentlemen would have it to be the same with *Boerhaave's* elementary fire. These different opinions seem neither to be grounded upon reason, nor supported by experiments.

THAT the first two opinions are erroneous, will admit of no dispute; for was the electric matter produced by friction, electric bodies could never by heat become non-electrics, it being the property of heat to rarify all bodies, even the most dense. Was it wholly supplied by the air, bodies would at all times be equally electri-

electrified, whether the machine stood on the earth, or was placed on electrics.

As to the last, I shall refer the favourers of that opinion to Doctor *Boerhaave's* treatise on fire; where they may be convinced, that the notions he entertained of that element, are very different from what is here advanced concerning electricity ^a.

^a To shew that this elementary fire differs from this electric matter, I shall set down some experiments and observations, which were communicated to me by Mr. *Smeaton*, the gentleman whom I have had frequent occasion to mention in this Treatise.

EXPERIMENT.

Upon heating the middle of a large bar of iron to a glowing heat, and then electrifying it, the electrical phenomena, to wit, the power of moving light bodies, and the explosion appeared to be much the same from the parts which were heated, and those which were cooler: so that the electric matter passed through the fire without any visible alteration.

OBSERVATION I.

Now as the supposed elementary fire filled the middle part of the iron bar, and was in some measure fixed therein, there is great reason to believe it would have obstructed the passage of a fluid of the same kind, absorbed it, dissipated it, rarefied it, rendered it more or less elastic, or at least have made some alteration in it, because we always find that two neighbouring vortices of electric matter have a visible effect upon each other, so also, two magnets assist, or obstruct each other according to the situation of their poles.

OBSERVATION II.

When a body is heated, the elementary fire is not in equilibrium in every part of that body; for a body may be very hot

BUT

BUT as it is unreasonable to destroy the hypotheses of others, without establishing some principles in their stead ; I have therefore endeavoured to show, That by friction a very subtle elastic fluid is accumulated or collected — which is capable of being diffused through some bodies, and not through others — the former are distinguished by the name of Non-electrics, the latter by Electrics — That this fluid may be accumulated more or less in non electric bodies — That when it is accumulated, it will expand and dissipate itself, and in the dissipation exhibit, various phænomena, according to the circumstances attending the experiment—That the explosion and the power of moving light bodies, is not as the quantity, but the density of this fluid — and that it is propagated along dense bodies with an exceeding great velocity

in one part, and less hot in another at the same time: whereas every body which is electrified, appears to be equally electrified in every part, and that whether it is equally hot or not.

EXPERIMENT.

The flame of a candle may be electrified.

OBSERVATION.

This is a farther confirmation, that elementary fire may be electrified.

To this I shall add, that with respect to the explosion, it may probably be owing to very volatile sulphureous parts, thrown off from bodies by the violent motion of the electric matter, which volatile sulphureous parts, mixing with the acid in the air, kindle into flame.

—That

—That this fluid, when it is accumulated in a body, will pass into those bodies which are nearest, and give the least resistance —That it is supplied from adjacent bodies and the earth itself —That the original quantity of this fluid in a non-electric body, may be lessened or increased—That when bodies receive a greater quantity of this fluid, than originally belonged to them; non-electrics that are contiguous, and the earth itself, must lose some part of the quantity of this fluid, which they originally had —That in certain circumstances, neither the attenuation nor accumulation of this fluid in a body, can by any methods, hitherto known, be made to exceed a certain degree—That the accumulation of this fluid, in some circumstances, is in the direct proportion, and in other circumstances, in the reciprocal proportion to the resistance it meets with, as it tends to dissipate—That nearly the same effects are produced by the attenuation, as by the accumulation of this fluid—That upon an explosion part of the accumulated fluid may be forced through mediums, which resist differently, and that, by the reaction of the particles of the fluid—That on causing an explosion with the vial, the whole quantity of accumulated electric matter that is dissipated, does not pass off at that part of the body where the explosion

plosion is made, but from all parts of the surface, even though it be covered with a thin electric—That the accumulated electric matter is not totally dissipated by repeated explosions—That when the electric matter is accumulated in the vial, the loudness of the explosion, and quantity of electric matter dissipated on completing the circuit, seem proportional to the points of non-electric contact with the out, and in side of the vial—That when the electric matter is accumulated in the vial, the greatest effects are produced by completing the circuit. How it comes to pass, that the greatest part of the accumulated electric matter is dissipated by one explosion, I have not taken upon me absolutely to determine; but in order to assist others, whomay pursue these inquiries farther, I have set down several experiments of different kinds, and from them proposed a query, concerning the manner in which it seems to be effected; and likewise, concerning the manner in which that painful shock or convulsion of the nerves and muscles, which is generally felt by animals, may be caused—That this strange effect seems proportional to the magnitude of the explosion—That we cannot determine, from the appearance of the divergency of the electric matter which body it issues from; because the electric matter both in passing out of a body,

and

and passing into it, has the same appearance—That if a person compleats the circuit, the greatest painful shock will be always felt in those parts, which lie in the shortest line that can be drawn through the person, from the covering of the vial to the wire—That non-electric bodies, placed at small distances without the circuit, will be affected in the same manner, but in a less degree, as if part of the electric matter had passed into them—That an explosion never happens, but when the issuing electric matter is very much condensed—That the greatest explosion is from polished surfaces—That the explosion is greater, the larger the surfaces are, to a limited degree, and—That dense bodies, in their natural state, are capable of receiving a greater quantity of electric matter, than bodies that are rare.

IN the second part, we have given a short account of the *æther*, Sir *Isaac Newton* has treated of; then compared it with the properties of the electric matter, and shewn, that they strongly resemble each other—We have therefore considered the electric matter as *æther*, joined with grosser particles, propelled from bodies by the force and vigour of its action—That according to the law of the *æther*, when a body is made rarer, the *æther* in that body must grow denser, and *vice versa*—That fric-

tion will cause bodies to rarify, as well as the heat of the sun or any other heat—and That those rarified bodies will contract and grow denser, on discontinuing the friction, or on removing their rarified parts from the friction—That as bodies grow rarer by heat, *æther* flows into them from other bodies—and as they grow denser by cold, *æther* flows out of them into other bodies—That when two bodies are rubbed against each other, the *æther* will flow in a greater quantity into the rarified parts of the bodies, than into those parts of the same bodies which are not rarified—And upon the parts of the bodies growing denser, the *æther* must pass out of these bodies, where it meets with the least resistance—That this flowing of the *æther*, which produces all the electrical effects, can only be caused by friction—That the flowing of the *æther* must gradually lessen on discontinuing the friction—and that the electric effects from the glass must grow weaker, as it cools and recovers its original state—That it is in some degree necessary for the cylinder to be turned always one way—That equal effects can never be produced in the bar from the cushion and glass, by the application of heat without friction—That two thick electrics, rubbed against each other, can never produce so strong electrical effects, as when an electric

and a non-electric are rubbed against each other —That setting the machine on non-electric bodies, moistening the leather of the cushion and all other circumstances, to keep an open communication with the cushion, are absolutely necessary for producing the greatest flux of the *æther*—That in order to see how far the *æther* is capable of being accumulated in a non-electric body, it is absolutely necessary to suspend, or set the non-electric upon some electric, which obstructs or resists the entrance of the *æther*, more than non-electric bodies do —and that the electric bodies should be always dry and free from dirt—That when the *æther* is put into such a motion within a body, as is described in prop. xvi. it will throw off, by the violence of its action, sulphur, and other matter lodged on the surface, or within the pores, where it is less intimately combined with, and united to the parts of, that body—That this sulphurous matter, when it is thrown off in any considerable quantity, ferments with the nitrous acid floating in the air, which fermentation is probably the cause of the sudden blast, or violent explosion observed in some of the electrical experiments—That *æther* is more subtile than light—That dense bodies have more light in their composition than bodies that are rare, unctuous and sulphurous ones except-

ed—That unctuous and sulphurous bodies have more light in their composition, than other bodies of the same density — That the power in bodies to refract, reflect, and inflect the rays of light, is nearly proportional to the quantity of light contained in them — That the inflective, refractive, or reflective power of a body extends itself but to a very small distance from the body — That this power seems to be caused by the mutual action of the light in bodies, and the *æther* at their surfaces — That it is of a very great density, and extends to a very small distance from the surface of a body — That the rays of light seem to be reflected regularly by virtue of this medium — That this medium, which we have called the refractive, reflective, or inflective medium, or, in one word, by *atmosphærule*, prevents the electric matter, when accumulated within a body, from issuing so fast as it otherwise would, if there was no *atmosphærule* surrounding that body — That the electric matter, when it issues suddenly through a dense *atmosphærule*, produces a greater effect than when it issues through a rare one — That in two or more circuits made at the same time, with the same vial, but with different bodies, the electric matter will pass only in that circuit, where there are the fewest *atmosphærule*; or, in other words, where the resist-

resistance is least—That this resistance may be lessened, as in the chain, by bringing the links into closer contact with each other—That the particles of air have probably *atmosphærulæ* similar to the same kind of bodies, which are grosser and larger—That a sufficient number of them, with such *atmosphærulæ* placed in a medium, such as the *æther*, may constitute an elastic fluid, resembling the atmosphere of the earth—That if any non-electric matter be put into a glass, whose *atmosphærule* is very great, and be afterwards electrified, the resistance the electric matter will meet with in passing out on completing the circuit, seems to be as the thickness of the glass, the quantity of non-electric contact with the glass, and the sum of the several *atmosphærulæ*; to wit, of the dissipator, the glass vessel, and the matter contained within it—That from the different density of the *atmosphærulæ* surrounding bodies, it principally is, that some are electric, and others non-electric, regard being always had to the texture of the bodies; those bodies which have the densest *atmosphærulæ*, supposing them not fluid, moist, or soft, are called electrics, and those which have the rarest *atmosphærulæ*, non-electrics—That any fluid may be electrified, though the *atmosphærulæ* of many fluids are much denser than that of common glass—

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—That electric bodies may be rendered non-electrics by heat, glass and amber not excepted — That hardness seems to be a necessary property for making bodies electric — That electric matter may be accumulated even in electric bodies — And that it will always pass away where the resistance to its exit or entrance is the least — That the electric matter passes off with a sudden motion, when its density in any particular part of a body exceeds the density of the *atmosphærule* — That the electric matter passes both into, and out of bodies, which have points and edges, more readily, than it does into and out of bodies of the same kind, which have no points or edges; and from those properties, we have endeavoured to explain several curious *phænomena*, in relation to pointed and edged bodies.

IN the xiv Sect. we have shewn the effects of electric matter upon light bodies, in confined air, and *in vacuo*, as well as in the open air — That the difference between thick and thin electrics of the same kind, and the alteration made in their effects by heating, may arise from a change in their *atmosphærelæ*, or in the texture of the parts of the bodies themselves — That if a given quantity of electric matter passes directly through any number of bodies of the same kind, placed in a right line
of

of a given length, the resistance given to its passing through them will be least, when it passes through the least number, and greatest when it passes through the greatest number — That the larger the body is, which a given quantity of electric matter is expanded in, the more that quantity will be rarified, and the more it is rarified, the less the resistance — From thence I gathered the reason, why the electric matter has a stronger tendency to pass into gross bodies; such as metals, fluids, &c. and the earth itself, than into dry air.

IN Sect. xv. which is the last, I have endeavoured to explain the nature of the force, by which light bodies are moved in electrical experiments, and attempted to shew, that it is the same force with that which causes gravitation; which force can be no other, than a fluid exceedingly more subtile and elastic, than air, at the surface of the earth.

WHAT I have said on these matters, is intended chiefly as hints, to excite others to make further researches. That many and useful discoveries will, one day or other, result from the doctrine here advanced, how crude and indigested soever it may now seem, no doubt, I think, is to be made. Abler hands may extend these inquiries farther, and probably complete what I have begun. I should not be sur-

prized, if the nature of muscular motion, vegetation, and even magnetism itself, should be hereafter explained upon the same principles.

HOWEVER this may be, what I have advanced seems to have the advantage of the several hypotheses hitherto framed for explaining the nature of electricity, as it is the most universal and consistent with itself; at the same time, that in the most plain and simple manner it accounts for the other phenomena in nature, as well as those in electricity.

If the existence of an *æther* be admitted, we may reason by analogy concerning other parts of this planetary system. Heat is observed to decrease in receding from the sun, and this decrease is demonstrated, to be as the squares of their distances. Was our earth then removed three times farther than it is from that luminary, the effects of heat would be nine times less; was it placed three times nearer, it would be nine times greater than in our present situation; in the former case, our water would freeze and become solid; in the latter it would be even hotter than boiling water, and be more easily evaporated. If therefore there are any fluids in the rest of the planets, which are in our system, their parts must be exceedingly rare in those farthest from, and ex-

ceeding dense in those which are nearest to the sun; for otherwise they could never be preserved in a state of fluidity by degrees of heat, which are so very different ^a.

LASTLY, as matter is in itself inert, the *æther* must of necessity receive its activity from an *infinitely wise*, and *powerful spirit*. This *æther*, from its being so general a material cause, may probably be the great instrument, by which the Almighty directs, governs, and supports the universe.

^a Prop. viii. Theorema viii. Cor. 4. *Newt. Princip.*
Denfiores igitur sunt planetæ qui sunt minores, cæteris paribus, sic enim vis gravitatis in eorum superficiebus ad æqualitatem magis accedit. Sed & denfiores sunt planetæ, cæteris paribus, qui sunt Soli propiores; ut Jupiter Saturno, & Terra Jove. In diversis utique distantjiis a sole collocandi erant planetæ ut quilibet pro gradu densitatis calore Solis majore vel minore frueretur. Aqua nostra, si Terra locaretur in orbe Saturni, rigesceret, si in orbe Mercurii in vapores statim abiret. Nam lux Solis, cui calor proportionalis est, septulo densior est in orbe Mercurii quam apud nos: & thermometro expertus sum quod septulo Solis æstivi calore aqua ebullit. Dubium vero non est quin materia Mercurii ad calorem accommodetur; & propterea densior sit hac nostra; cum materia omnis densior ad operationes naturales obeundas majorem calorem requirat.

EXPERIMENTS

UPON

HUMAN BODIES.

IN the month of *May* 1748, I had an opportunity of trying the effects of electricity upon a woman in *London*, who had been deaf many years; she was born in the island of *Nevis* in the *West-Indies*, and was about 28 years of age. Her name is *Mary Smargins*.

SEVENTEEN years ago, she became so deaf as not to hear any one, unless they were very near, and spoke loud to her. This deafness proceeded first, as she believes, from a cold, and was never observed to be better at intervals. She always heard the least with the left ear; and when at any time the right ear was laid upon a pillow, or stopped, she could distinguish loud sounds but very faintly.

I WAS the more induced to make a trial of the electrical effects in this case, not only from what I was informed had been done at *Paris*, in cases of the like nature, but also from what *Mrs. Smargins* herself told me. That a few days before, upon her being electrified with other persons in my apartments by the vial, she felt a very unusual warmth across the stomach and

and in each arm, which continued for some time: that on the next day, she had observed a running at her nose, which she attributed to her having been electrified, and which she imagined was of some little service to her. For these reasons, and from an opinion, that the cause of this deafness might proceed from some obstruction in the auditory nerves, which might probably be removed by the violent effects of this subtile electric matter; I proposed to her, the giving the electrical shock, with the vial, across her head.

ON *Saturday* the 28th of *May*, I made the first experiment in the following manner.

THE covered vial being electrified by two turns of the wheel only, I applied the end of a thick wire, which was fastened to the covering of the vial, to the left temple, just above the ear; then I brought the end of that wire, which was in the vial, towards the opposite part of her head, and there ensued a small explosion. She was much surprized, and perceived a small warmth in her head, but chiefly across it, from ear to ear. I repeated the experiment four times, and made the electrical shock stronger each trial. The warmth excited by the shock increased in each experiment, and though I caused the experiment to be made at each ear alternately, she always found

found the warmth to be greatest in that ear she heard the least with. At last she complained of small twitchings in her ears and across her head, but mostly in that ear she heard the least with. When these experiments were made she did not perceive that any other part of her body was affected by the shock. All this day the warmth increased, and at intervals she felt twitchings in her ears. Her hearing she imagined was something better, so did the people with whom she lodged. She was advised to keep her head warm. I was informed that in the evening, she washed her head in cold water. The next morning early, which was *Sunday*, I repeated the experiments again in the same manner, and nearly with the same strength. At this time she complained of her arms and body being affected by the shock, and said that I had made it much stronger than the day before. The warmth seemed now quite round each ear, but still greater round that with which she heard the least; the twitchings were also more violent. These effects continued all the day. There were several signs this day of her hearing better. For in her lodgings she heard the bells ring, which she had never done before; and the gentlewoman with whom she lodged, observed, that she could understand what was said to her, though
spoken

spoken in a moderate tone of voice. After these experiments, notwithstanding she was advised to take particular care of catching cold, she sat at night in the window above an hour with the sash open, and her cap pinned up. This evening the warmth left her, and was succeeded by a great coldness in her head, and a chilliness all over her body.

THE next morning, which was *Monday*, she was extremely ill, with pains all over her. I did not care to try any more experiments whilst she continued in this disorder.

ON *Tuesday* she was much better, the coldness abated, and she felt again round each ear the same kind of warmth which she had before observed. — This day she mentioned several circumstances, which shewed her hearing was better, particularly the following ones. She could distinguish the cries in the streets, and the barking of dogs; and could hear people in the house with her going up and down stairs, though she herself sat in the uppermost room of the house.

ON *Wednesday* she was something better in all respects, and the noise and continual beating in her head, which she had had from the first of this misfortune, began now to abate considerably. In the evening a very violent shooting (as she expressed it) went across her head,

head, from the left to the right ear. This day I did not repeat the experiments, but on the day following, which was *Thursday*, I did. Some minutes after making them, she had occasion to blow her nose, when there issued corrupted matter with a small quantity of clotted blood. All this morning she felt in her head a glowing warmth, greater than had ever been before. This day, as she was resting her head upon a pillow, she heard the cries in the street, notwithstanding that ear with which she always heard the most, was close to the pillow, and was so surprized and rejoiced, that she got up immediately, to acquaint the gentlewoman of the house with it. At noon she heard a person at the bottom of the stairs calling her down to dinner, though the door of the chamber in which she sat, was at that time shut. Several times that day, I spoke to her in a lower tone of voice, than is usual in conversation, and she gave me direct answers to the questions I asked her. She said the noise and beating in her head was then almost intirely gone.

THIS day she could hear the opening and shutting of the street door. In the evening Dr. *Bevis* (whose name I have mentioned in the preceding Treatise) called upon me, as also did two other gentlemen, when I related to them this affair, and at the same time, desired they

the would step with me to her, and ask such questions as they should think proper. Upon my speaking to her in a very moderate tone, to my great surprize, she desired I would not talk so loud : and what is very remarkable, she had at this time cotton in both her ears, two caps pinned close about them, and a velvet hood on, to keep her warm. As I was obliged to leave town the next morning, I told her, that in my absence Dr. *Bevis* would be so kind to repeat the experiments, if she thought it necessary — This she declined, saying, that she could not find there was any occasion ; for that she heard very distinctly, and her head was very easy.

I FORGOT to mention one circumstance, which was this ; she had a great cold, and her eyes were much inflamed at the time I began to make these experiments. The inflammation decreased after the first experiments on *Saturday*, and it was intirely removed after the second experiments on *Sunday*. The disappearing of which inflammation, she solely attributed to the electrical effects. From that time to this, I have not been in *London*, but have had several letters from my friends, giving an account, that she continues to hear very well.

I HAVE tried these experiments upon six other persons, whose complaints were deafness,
but

but without any success. Three of them indeed fancied themselves better for a few days. One of the others, instead of receiving any benefit, complained of a violent pain in his head, and a dimness in his eyes; which he said continued for ten or twelve days after the experiments were made.

A GENTLEMAN near seventy years of age, was desirous to feel the shock, occasioned by approaching the vial. I was afraid of electrifying the vial too strongly at the first trial; but upon his declaring he scarcely felt any pain, I electrified it much stronger the second time, and afterwards as strongly as I could; nevertheless he was not affected, as is usual, in the arm and across the breast, but only in his wrists.

IN *August* 1748, I had occasion to try some experiments, in order to observe the different effects produced by a person's completing the circuit with the vial, in different manners; the experiments were of the same kind, with those mentioned in the ixth proposition. I made use of my own servant, who was about 25 years of age. After the first and second experiments, he complained of his spirits being depressed, and of being a little sick. Upon making the fourth experiment, he became very warm, and the veins of his hands and face swelled to a great

great degree. The pulse beat more than ordinarily quick, and he complained of a violent oppression at his heart (as he called it) which continued along with the other symptoms near four hours. Upon uncovering his breast, it appeared to be much inflamed. He said that his head ached violently, and that he felt a pricking pain in his eyes and at his heart; and a pain in all his joints. When the veins began to swell, he complained of a sensation which he compared to that arising from strangling, or a stock tying too tight about the neck. Six hours after the making of the experiments most of these complaints left him. The pain in his joints continued till the next day, at which time he complained of weakness, and was very apprehensive of catching cold. On the third day he was quite recovered.

THE shocks he received were trifling compared with those which are commonly received by most persons when they join hands to complete the circuit for amusement. His being affected more than ordinary might be owing to his constitution; for he was consumptive, and had been so for a long time before the making of these experiments.

WHEN the experiment with the vial was first made by *Muschenbroeck*, soon after I discovered a method of increasing its effects, and

was then able to indure the most violent shocks along my arms and across the breast : but upon repeating those shocks often for several weeks together, I at last was weakened so much that a very small quantity of electric matter in the vial would shock me to a great degree, and cause an uncommon pain. So that I was obliged to desist from trying any more. Whether it had any effect upon my health or not, I cannot say ; but even to this day I am affected nearly in the same way by the electrical shock.

IN order to shew how strongly my arms were convulsed, after I had been weakened by frequent repetitions of these experiments, I shall mention one experiment which the following accident gave rise to. I undesignedly touched the wire in the vial when it was electrified at the time that I had a slender brass wire in my hands, and the shock was so great that it broke the wire into two pieces and hurt both hands. I then thought of trying it with a thicker wire, and after a more secure manner : for this purpose I fixed a piece of leather round each wrist, and fastened a wire about the thickness of a very slender knitting-needle to each leather. I then with one hand took hold of the covering of the vial when it was strongly electrified, and with the other I approached the wire in the vial : on doing this there issued a very violent

lent shock or convulsion of the muscles of my arms and body, and the wire which was fastened to the two leathers was broke asunder about three inches from the middle. The length of the wire from wrist to wrist was about fourteen inches.

UPON rubbing with my hand a glass globe which was turned round on its axis, I have at different times been affected with a very violent head-ach, which always went off upon discontinuing the rubbing of the globe, and quitting the room.

I HAVE met with many persons who complained that they have found an unusual pain to continue for some days after receiving the shock.

I HAVE been assured from several persons who made the experiments, that the electrical shock has been of great service in removing many disorders, particularly fixed rheumatic pains; but I cannot say that it was of any remarkable service in four or five cases of the same kind where I tried it.

Miscellaneous Experiments.

EXPERIMENT I.

TWO pendulums of equal lengths suspended on the same horizontal line, which was about seven feet from the floor of the room, were made both to vibrate at the same time. Upon electrifying one of them, I observed that the pendulum which was electrified vibrated quicker than the other which was not, and still more so the nearer the ball of the pendulum was to a non-electric body which was not electrified.

EXPERIMENT II.

HAVING filled a vessel with water, and immersed one end of a siphon therein, I set the vessel upon wax and covered it with a glass receiver, the sides of which were moistened with water to render it non-electric. I then electrified the receiver and siphon, and found that, while the siphon was covered with the receiver, the water did neither flow faster out nor spread to a greater distance than it did when they were not electrified. But upon taking away the receiver, the water immediately spread to a considerable distance.

N. B. THIS

N. B. THIS last experiment may serve to shew that the motion of the blood is not increased by electrifying the animal. For the vessel and siphon covered with the receiver may be looked upon in nearly the same light with the body of the animal, the flesh and skin covering the veins and arteries as the glass receiver does the siphon; and in both cases the surrounding bodies being non-electrics. When the glass is taken away, the water spreads, from the great tendency the electric matter in the water has to pass into the adjacent non-electrics which are not electrified. And for the same reason, the blood, upon being electrified, will, when a vessel is opened, spread to a greater distance.

EXPERIMENT III.

I HAVE been able by striking solid bodies together very briskly, to produce a light resembling that produced by the electric matter, nay, even by striking my hands one against the other when they were very dry, I have produced a faint bluish light, which disappeared almost the instant the stroke was over. But for this last experiment it is necessary that the room should be very dark, and that the person should be some time in the room before he tries it, that the pupil of his eyes may be sufficiently dilated.

EXPERIMENT IV.

IF a tube of glass and a bar of iron be electrified, the one by friction and the other by the cylinder, to such a degree as that each of them shall move a light body from the same distance; the glass tube will retain electric matter longer than the bar, as appears from the light bodies continuing to be moved for a longer time towards the tube than towards the bar.

THE glass tube, when electrified, must be either laid upon or suspended by electrics.

EXPERIMENT V.

WHEN the bar is electrified, if a person standing on the earth touches very lightly with one hand a non-electric, at the same time that his other hand approaches the electrified bar, he will not only feel a smart sensation in the hand next the bar, but also in the hand touching the non-electric. If one, two, three, or more persons at the same time touch very lightly with their fingers different parts of this person, and one two, three, or more persons at the same time touch lightly different parts of these persons, and continue to do so when the first mentioned person approaches the bar; immediately on his causing the explosion from the bar they will all feel a smart sensation, but none will feel it so strong as the person who
causes

causes the explosion. In this experiment all the persons concerned are to stand upon the earth. See page 15, and proposition xii.

EXPERIMENT VI.

I SET a glass tube open at both ends, which was about twenty-four inches long, and three inches wide, upon an air-pump; the uppermost end was covered with a plate of metal and leathers: a moveable wire about twenty inches long was put through this plate in a collar of leathers, and at the end of this wire within the tube was suspended a brass ball. Then after having exhausted the tube and electrified the coated vial, the wire which passed into the vial was brought near to the moveable wire in the plate, at the same time that a chain communicated with the outside covering of the vial and the top of the air-pump. On doing this, it seemed as if part of the electric matter which was accumulated in the vial, passed out of it and through the dissipator; though the distance of the brass ball from the bottom was about twelve inches. For the experiment being made in the dark, a light was seen to dart in rays from the ball towards the air-pump.

EXPERIMENT VII.

THIS last experiment was repeated, and a person made part of the circuit without receiving the convulsive shock.

EXPERIMENT VIII.

UPON lowering the ball no change appeared, except that the light within the glass seemed a little brighter.

EXPERIMENT IX.

WHEN the ball was raised twenty or fifteen inches, there was no light within the glass.

EXPERIMENT X.

ON letting in part of the air, and trying all these experiments over again, no light was seen in the glass, nor did it appear that any electric matter escaped out of the vial upon compleating the circuit in the manner we have now been mentioning. See page 84 and 85.

I DESIRED a friend of mine, who has made the new kind of air-pump which I have mentioned before, and to whom I owe the contrivance of the electric machine represented in the first figure, to try what would be the effects in an electrified glass when the air was exhausted; and the account he has transmitted to me of the experiment is as follows.

A GLASS whose length was about one foot, and greatest diameter eight inches, open at both ends, had one of its ends closed by a brass ferril, which constituted one of the centers on which it turned: the other end was closed with a metal plate: in the center of this plate was a square stem, which was applied

plied to the arbor of a lath by which the glass was turned round. On one side of this last plate was fixed a cock, by means whereof the glass was screwed upon the air-pump.

UPON rarifying the air within the glass about five hundred times, and afterwards turning the glass in the lath, whilst at the same time it was rubbed with my hand, a considerable quantity of lambent flame, variegated with all the colours of the rainbow, appeared within the glass under the hand: this light was pretty steady in every respect, except that every part of it was perpetually changing colour. When a little air was let into the glass, the light appeared more vivid and in a greater quantity, but was not so steady, for it would frequently break out into a kind of corruscations like lightning, and fly all about within the glass. When a little more air was let in, this flashing was continual, and streams of bluish light seemed to issue from under my hand within the glass in a thousand forms with great rapidity, and appeared like a cascade of fire. Sometimes it seemed to shoot out into the forms of trees, moss, &c. When more air was let in, the quantity of light was diminished, and the streams composing the flashes narrower. The glass now required a greater velocity and harder friction. These circumstances

stances increased as more air was let in : so that by such time as the glass was one third full of air, these corruscations quite vanished, and a much smaller quantity of light appeared partly within and partly without the glass. And when all the air was let in, the light appeared wholly without the glass, and much less in quantity than when the glass was in part exhausted.

EXPERI-

EXPERIMENTS

U P O N

Artificial Magnets.

MR. Bosc, professor at *Wittemburgh*, in a letter to the Royal Society in *London*, gave an account that he had been able, by the effects of electric matter meerly, to invert the poles of natural magnets, destroy their virtue intirely, and give it again *de novo*: but did not take notice of the method he made use of for that purpose: nor have I yet heard of any one person who has succeeded in the making of these experiments.

As I did not think it impossible that some change might be made in the powers of magnets by the electric matter, I was induced to try several experiments of this sort. And tho' I did not observe any remarkable change, I thought an account of the several experiments would not be unacceptable in this Treatise.

THE magnets I used in the following experiments were made by Dr. *Knight*, each of them about eight inches long.

EXPERIMENT I.

HAVING observed the greatest weight each of them could lift, which was nearly equal, I suspended one of them by a thread fifteen inches long to the end of the bar B B, with the north pole uppermost, and caused the wheel to be turned twenty minutes. On taking it from the thread, I found that it raised the same weight it did before it was electrified.

EXPERIMENT II.

I THEN suspended the same magnet again, but with the south pole uppermost, and after it had been electrified for the same length of time, I removed it from the thread, and found that it raised the same weight.

EXPERIMENT III.

By holding the north end of one of the magnets near a brass globe suspended by the electrified bar, I caused several explosions between the magnet and globe; and on taking it away, I did not find any alteration made in its power.

EXPERIMENT IV.

UPON repeating the experiment with the south pole next the globe, no visible alteration ensued.

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EXPERIMENT V.

I SET the vial with the filings, after they were strongly electrified, upon wax, and then taking one of the magnetic bars in my hand, I made the north pole approach the wire in the vial at the same time that I touched a brass wire fastened to the outside covering of the vial with the south pole: so that in this case the magnetic bar was the dissipator. And on doing this a large explosion ensued, by which the greatest part of the electric matter accumulated in the filings was dissipated. I repeated the experiment several times, and could not find upon examining the power of the bar, that it had undergone any change, either with respect to its polar or magnetic virtue.

EXPERIMENT VI.

I REPEATED the same experiment an equal number of times, with the south pole uppermost, and did not find any sensible change in the magnet.

EXPERIMENT VII.

I SUSPENDED the same bar again with the north pole uppermost, and then brought a thin plate of glass, which was laid on the palm of my hand, into contact with the south pole of the magnet, and there continued holding it whilst the wheel was continually turned for near thirty minutes. On my taking away the magnet

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magnet, and trying its strength, I found no variation, nor indeed any alteration in its poles.

EXPERIMENT VIII.

I REPEATED the experiment with the south pole of the magnet uppermost, and the success seemed to be the same.

EXPERIMENT IX.

AFTER suspending the same bar again in thread to the electrified bar, I brought very fine filings of iron near it, and observed that the filings did not adhere to the bar so strongly as when it was not electrified.

EXPERIMENT X.

INTO a vial filled with quicksilver and covered on the outside with lead, I put one of the magnetic bars instead of the crooked wire w, the north pole of the magnet being without the neck of the vial. After electrifying the vial for a considerable time, I found that the magnet had neither lost nor gained strength.

EXPERIMENT XI.

UPON repeating the experiment with the south pole, no alteration was observed.

EXPERIMENT XII.

I THEN put the same bar into the vial with the north pole out as before, and when the quicksilver and magnet were strongly electrified, I brought the end of a dissipator made of

brass near the bar, and caused an explosion. I repeated this experiment about forty times, and, upon examining the power of the magnet, I perceived little or no alteration; the difference, if any, was a diminution of its virtue.

EXPERIMENT XIII.

I REPEATED the experiment with the other bar, the south pole being without, and so far as I was able to observe, there did not appear to be any remarkable difference.

EXPERIMENT XIV.

THE vial and bar being electrified as in the former experiment, instead of making use of a piece of brass to cause the explosion, I used one of the magnets as a dissipator, and placed the south pole of one near to the north pole of the other, with a piece of brass eight inches long between the poles, to prevent them acting upon one another. And to prevent the magnet which was without the vial from being affected by the bar within, and the iron wire surrounding the vial, there was another piece of brass eight inches long in contact with the covering of the vial, and the other pole of the magnet. On electrifying the vial, and causing several explosions, I found that both the magnetic bars retained nearly their former virtue.

The E N D.

E R R A T A.

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	13.	12.			fig. 2.
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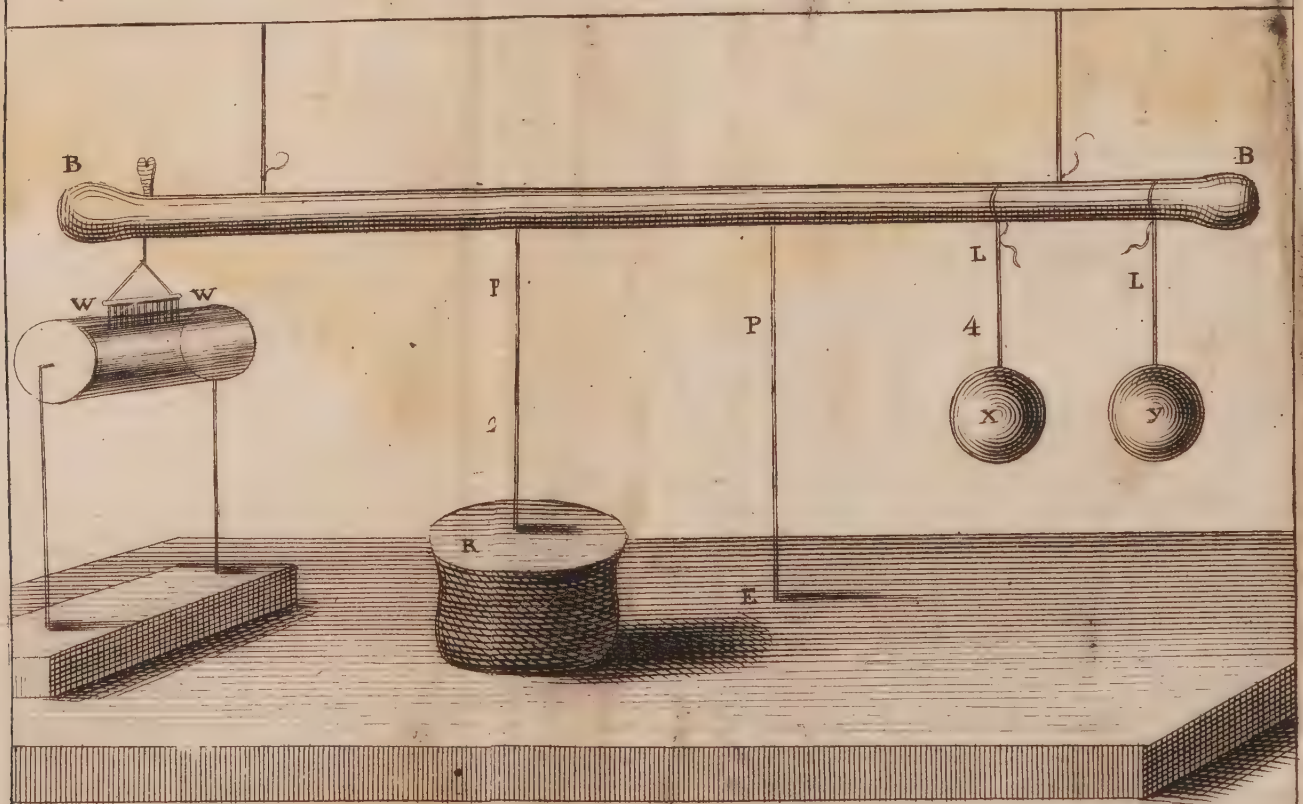
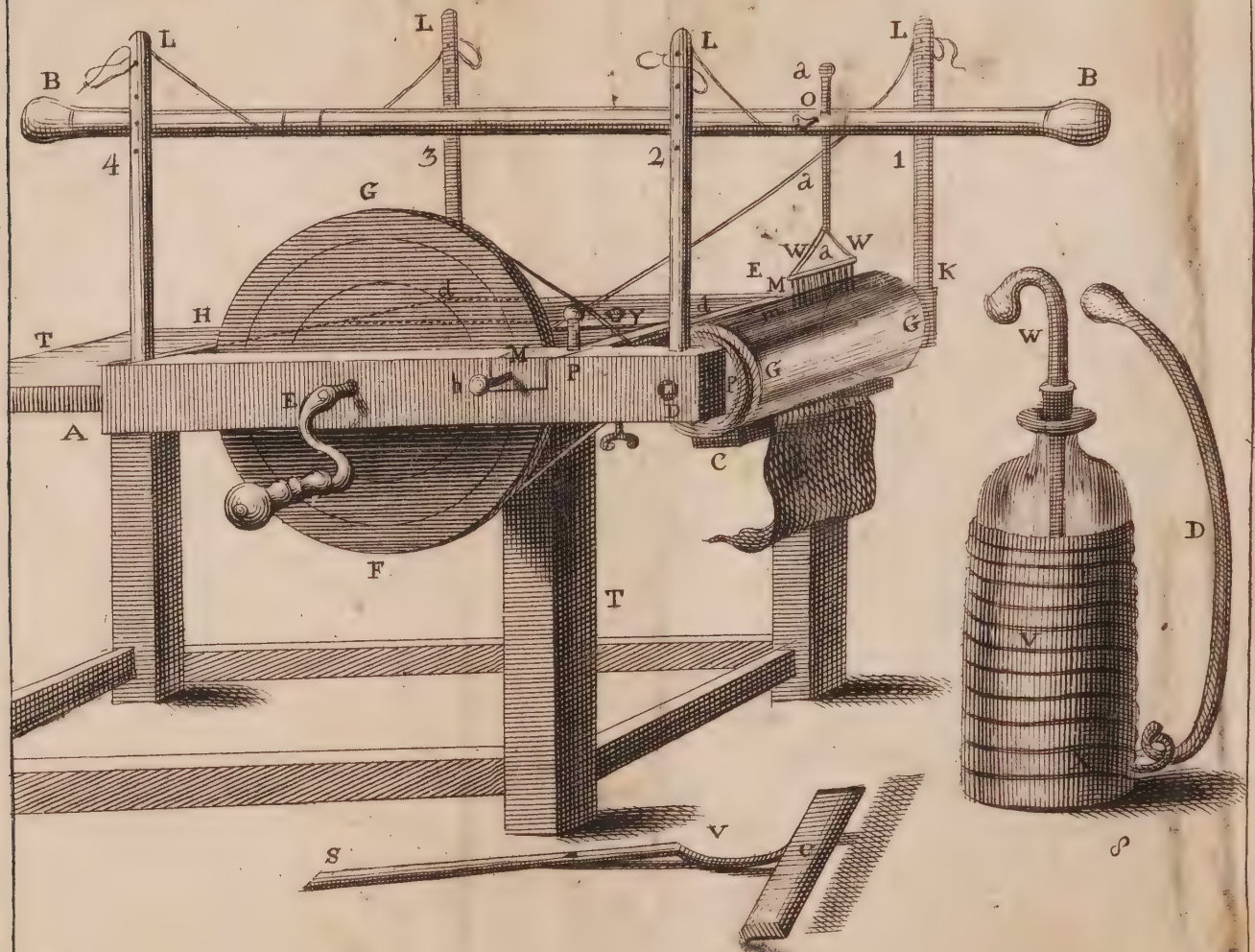


Fig. 3.

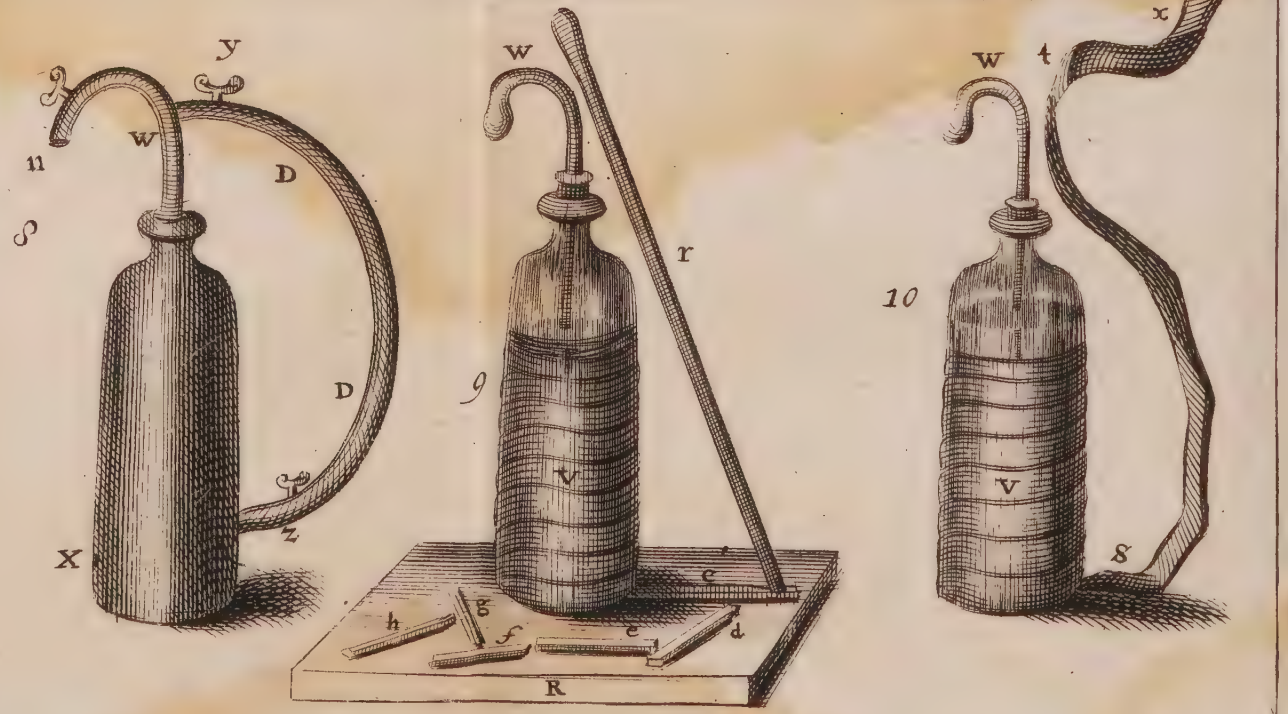
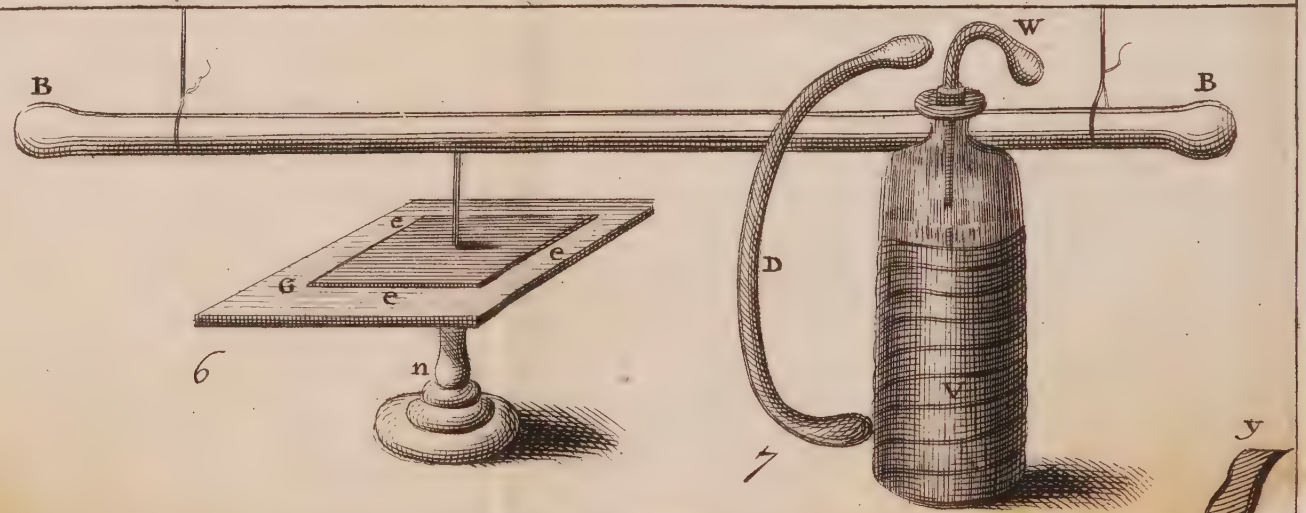
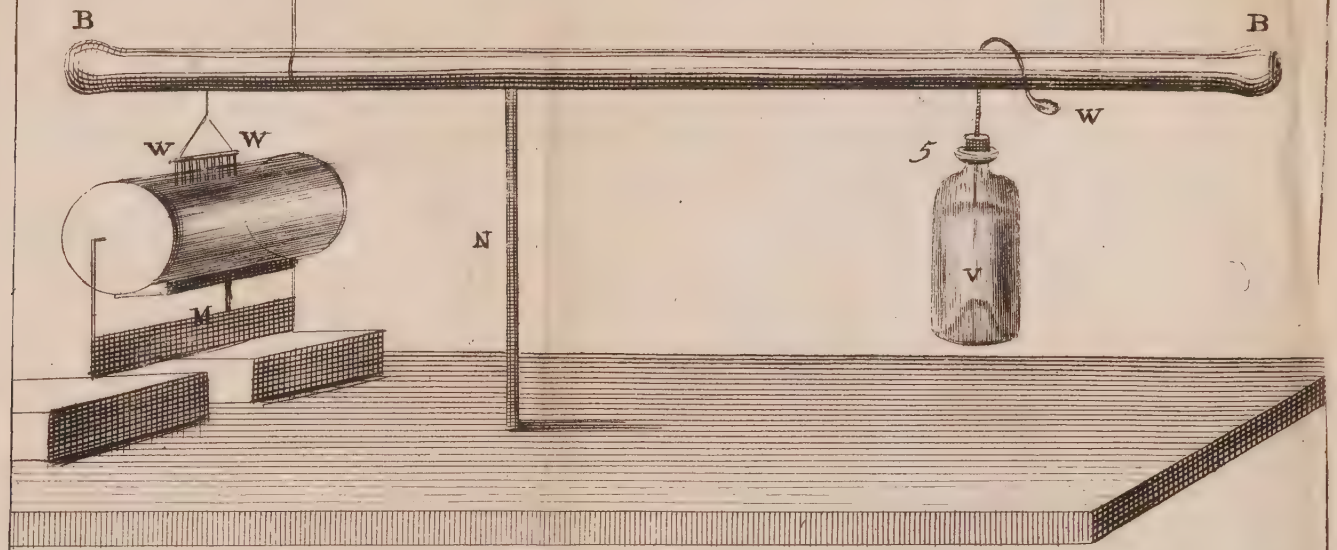


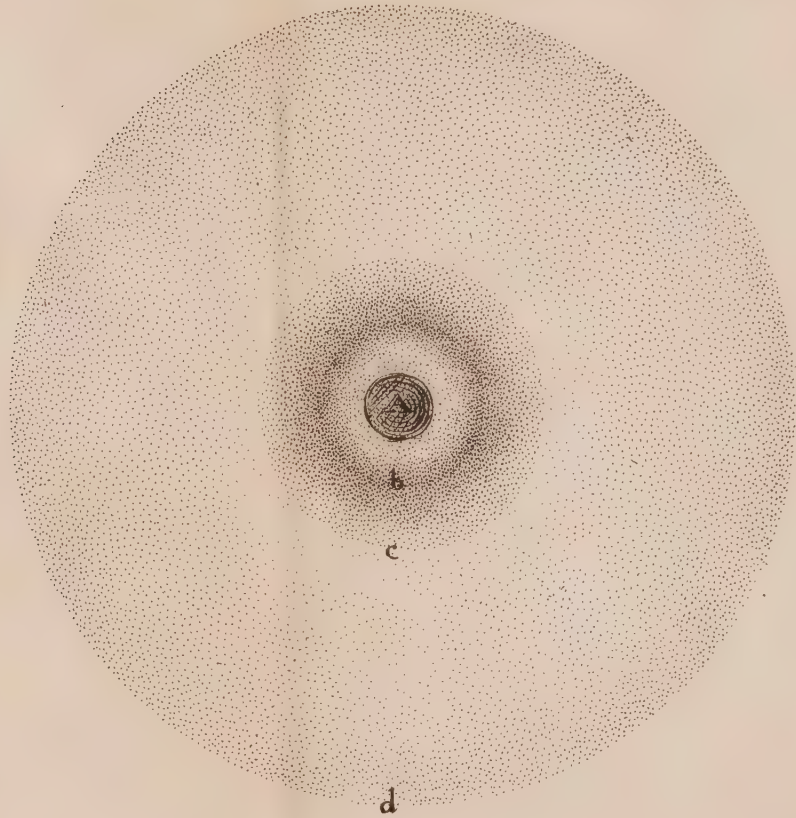
Fig. 12.

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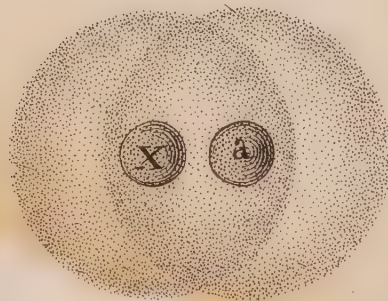
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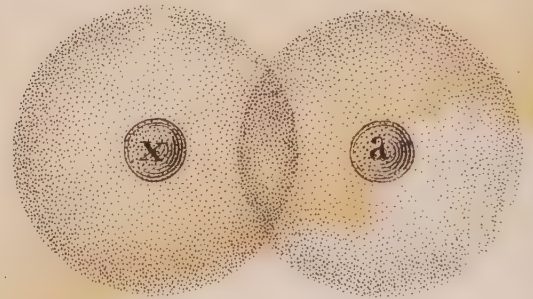
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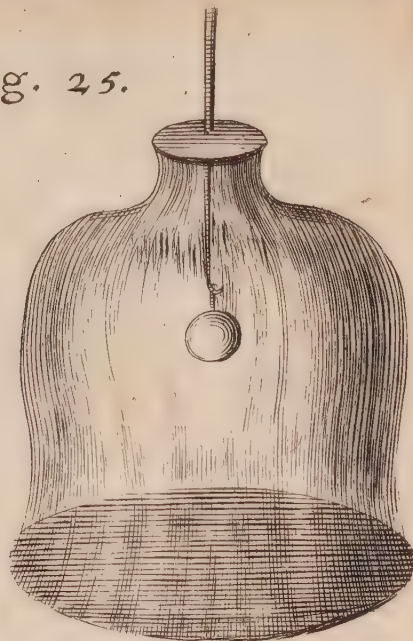
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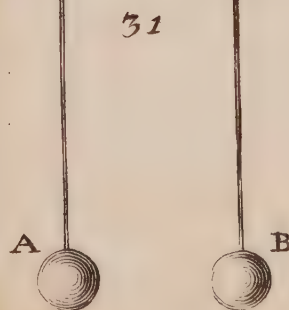
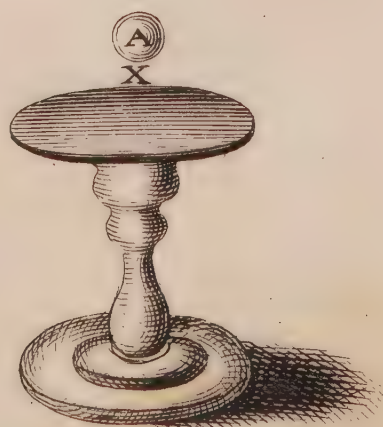
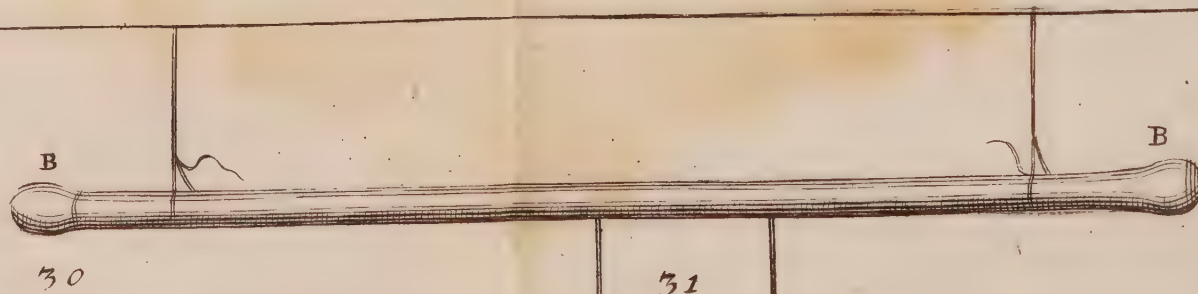
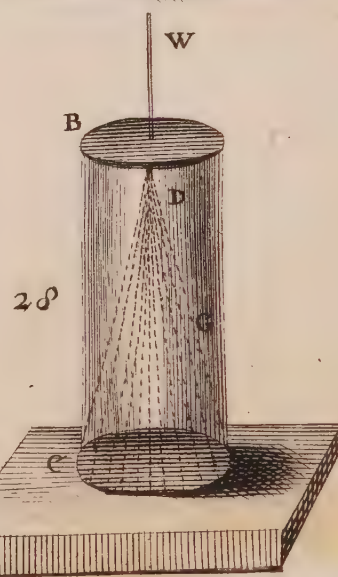
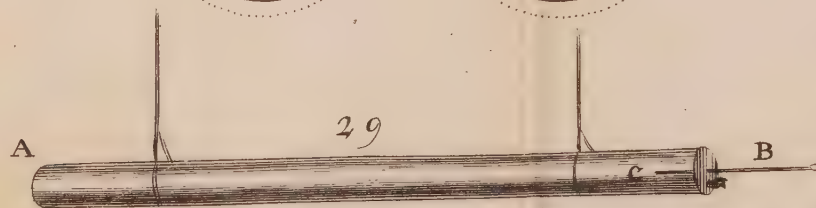
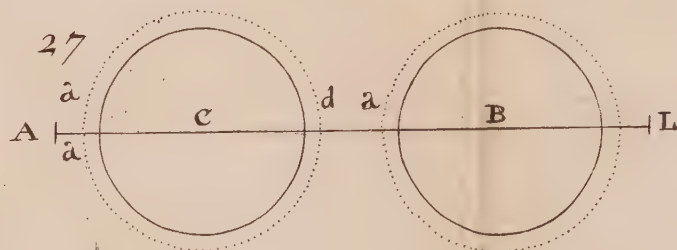
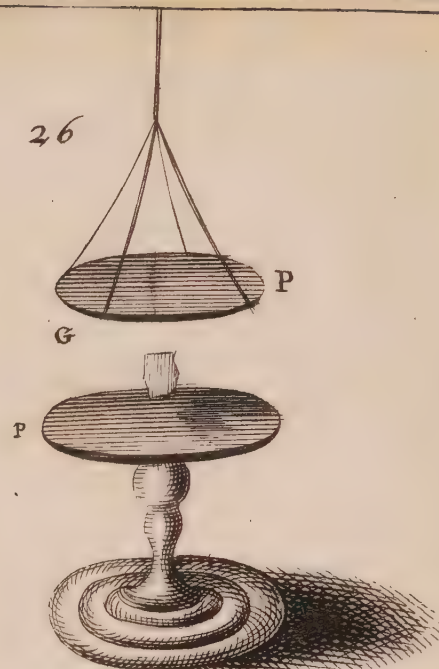
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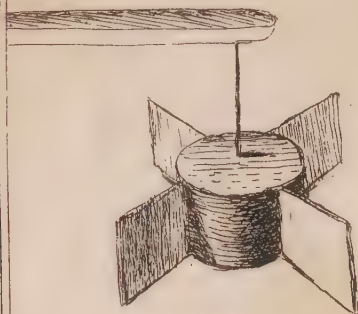
Fig. 25.



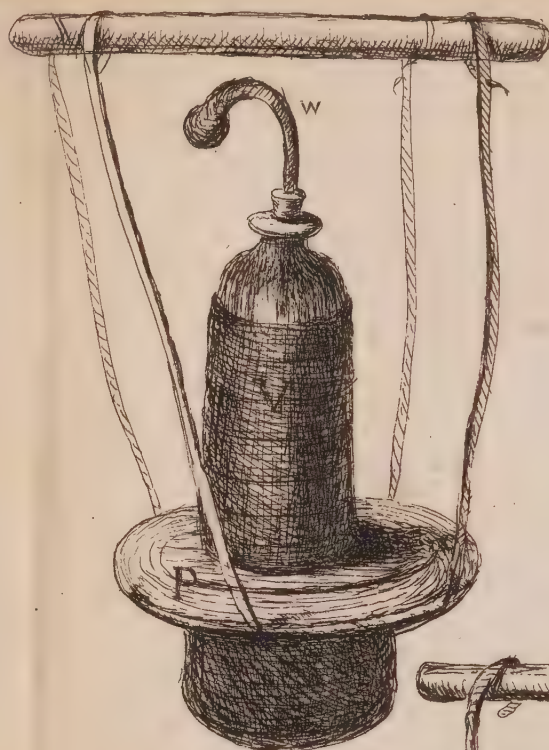
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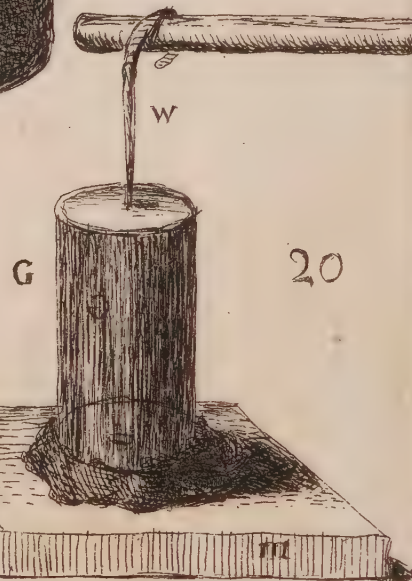


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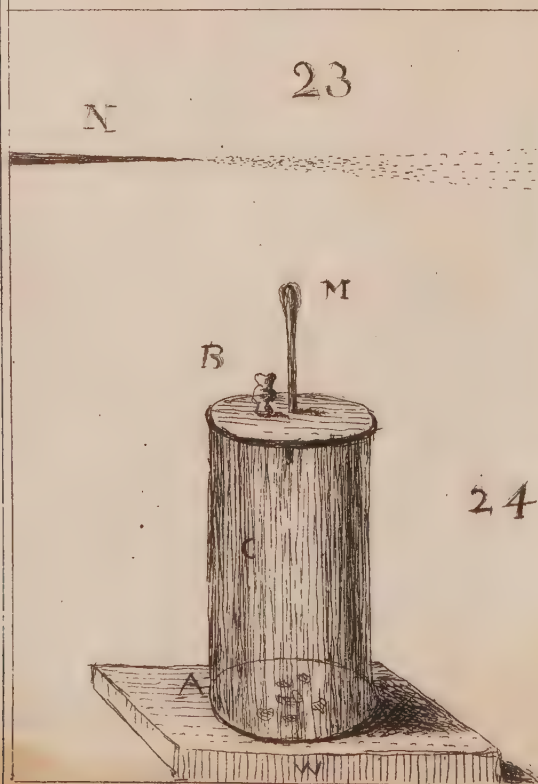
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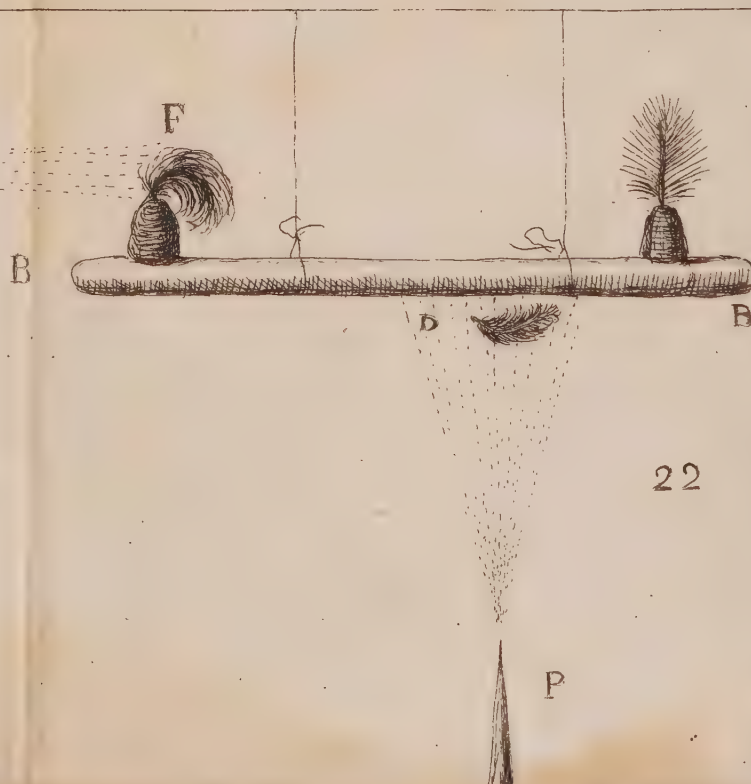
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